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ANNUAL TAPPI ISSUE

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# Paper TRADE JOURNAL

REG. U. S. PAT. OFF.

VOLUME 125, No. 19 NOVEMBER 6, 1947

WOOD PULP

G

*Established 1886*

"To see the world in a grain of sand
And a heaven in a wild flower,
Hold infinity in the palm of your hand
And eternity in an hour."

BLAKE

A dream of a mighty nation emerging out of a wilderness! The imagination to harness the resources of a vast territory into the most productive economic system known to man! The vision and ingenuity of diligent Americans who made possible the world's highest standard of living!

This is the story of America, an amazing record in which the Pulp and Paper Industry has well performed its share.

**GOTTESMAN & COMPANY**

— INCORPORATED —

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# CONTROL...Yes

# But HOW EFFICIENT?

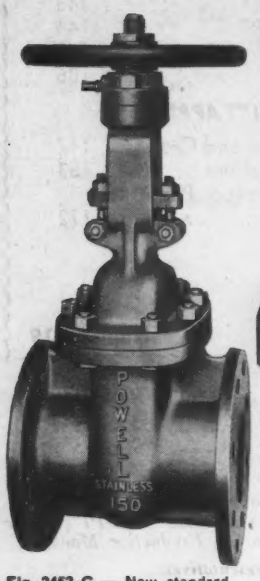



Fig. 2453-G — New, standard 150-pound Stainless Steel Gate Valve with outside screw rising stem, bolted flanged yoke-bonnet and taper wedge solid disc.

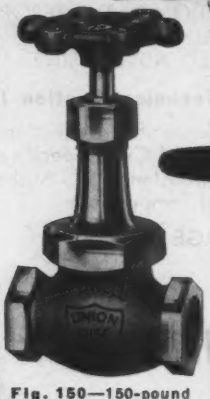



Fig. 150—150-pound Bronze Globe Valve with screwed ends, union bonnet and renewable composition disc.

Fig. 1793—Large 125-pound Iron Body Bronze Mounted Gate Valve. Made in sizes 2" to 30", incl. Has outside screw rising stem, bolted flanged yoke and taper wedge solid disc.

Fig. 1944–Large size 150-pound Stainless Steel "Y" Valve with flanged ends, bolted flanged yoke-bonnet and outside screw rising stem. Sizes 2½" to 12", inclusive.

It's a long step from the Old Mill wheel to the modern power plant. Much of the difference lies in the degree of efficiency in flow control.

More than a century ago, when Powell started to make valves, industrial flow control requirements were simple. Since then the immense growth and diversification of American Industry has multiplied the demands for diversification of flow control equipment a thousandfold.

Through these many years Powell has been meeting each and every demand as it has arisen. That's why today the Powell Line is unique in that it includes valves of the right type, size, design and material to satisfy *every* known requirement of modern industry.

**See our exhibit in BOOTH 54**
**21st Exposition of Chemical Industries**
**Grand Central Palace, New York City**
**December 1 to 6, 1947**

## The Wm. Powell Company
**Cincinnati 22, Ohio**

**DISTRIBUTORS AND STOCKS IN ALL PRINCIPAL CITIES**

# POWELL VALVES

Paper TRADE JOURNAL

VOL. 125, NO. 19 REG. U.S. PAT. OFF. NOVEMBER 6, 1947

## Ontario Threatened By Power Shortage

TORONTO — Processors of paper and paper products in the older and lower part of Ontario will all be affected by the present shortage of electrical energy, which is growing more acute daily with the advancement of the season from autumn to winter. December and January will be the most critical months.

The provincial government took steps this week to ration electrical power, if that becomes necessary. A bill before the legislature would empower the Ontario Hydro-Electric Power Commission, and also municipalities, to "control" and "restrict" distribution of power in an emergency and would impose penalities of $100 a day for violation of any such orders.

Hydro Vice-Chairman Ross Strike agreed that rationing was difficult, and voiced hope that voluntary reduction in power consumption might make it unnecessary. The commission's target is to save 10 percent in consumption during peak hours, 7 a.m. to 9 p.m. Power rationing, which would give everyone the same chance, would probably affect earnings of paper processors in this area, because firms with advance business in sight, if curtailed in their power requirements during the day, would seek to make up the production by working a shift beginning at 9 p.m., which, of course, would be costly on account of the difference in pay for night and day workers or overtime work.

In spite of the building of vast new plants, the power producers of Ontario and Quebec cannot keep pace with the demand for electrical energy, so fast is the pace of industrial development in this part of the country.

### Millprint Abandons Kaukauna Project

KAUKAUNA, Wis. — Millprint, Inc., Milwaukee paper packaging company, has abandoned the idea of a branch plant at Kaukauna, Paul Hultkrens, manager of Millprint's cheese packaging division, has informed Mayor Joseph F. Bayorgeon. Mr. Hultkrens said that it would be of advantage to his company to locate the branch at its own plant at De Pere.

Millprint had given serious consideration to a Kaukauna branch, and officials had arranged for a meeting with the common council, but this meeting was postponed, and now has been canceled.

### Kimberly Staff Wins Wage Adjustment

KIMBERLY, Wis.—Approximately 590 employes at the Kimberly mill of Kimberly-Clark Corporation have been granted rate adjustments of from 1 to 10 cents an hour, according to George Truscott, president of the Papermill Workers Union. The adjustment resulted from negotiations, and will cost K-C about $55,300 annually.

In addition, Truscott said, the membership will receive pay for three holidays not worked — July 4, Labor Day and Christmas. An additional five days or 40 hours of sick leave were granted, making a total of 200 hours available for sickness to those employes who have not taken any sick leave during the 5 years of the plan's existence. The provisions became effective September 29 with exception of the sick leave benefits which will go into effect next January 1.

### B-S-W Ships First Pulp From Its New Mill

PORT ALBERNI, B. C.—Initial shipment of pulp from the new plant of Bloedel, Stewart and Welch has been sent to England. The first shipment of 1000 short tons left Port Alberni on the Seaboard Trader enroute to the United Kingdom. Shipment was consigned to the government controller in England, who will apportion it to British consumers.

### Allan Hyer Joins Bagley & Sewall

WATERTOWN, N. Y. — Allan Hyer, who for many years has been prominently identified with the paper machinery field for many years, has joined the Bagley & Sewall Company of this city. In making known the news of his appointment Abe Cooper, president of Bagley and Sewall, let it be known that he was extremely happy not only to have a man of Hyer's prominence added to the company's forces, but also a man whose attainments in his field are based on a solid knowledge of its trends.

## Philadelphia Stages TAPPI's Second Engineering Conference

PHILADELPHIA — More than four hundred pulp and paper mill engineers gathered this week in this city for the second annual Engineering Conference of the Technical Association of the Pulp and Paper Industry. They found a busy schedule set up for their attention, with a three-day program of papers prepared by authorities in their fields, a broad selection of machinery plants to be visited, and a generous amount of time set aside for informal visiting and interchange of ideas among those of kindred interest.

Abstracts of the papers on the formal program are presented elsewhere in these pages. A more complete account of the social interludes at which those attending will be guests of some of the big paper mill machinery firms in this area will be given next week.

The dinner on Monday evening proved to be a stimulating start for the affair. Coming after the first day of papers, it was held at the Adelphia, under the guiding hand of W. F. Gillespie, TAPPI president. Brief talks were given following the dinner, by J. E. Rhoades, by R. S. Johnston, vice-president of the Pusey & Jones Company, and by E. Street, vice-president of the Downingtown Manufacturing Company.

Chief speaker of the evening was Dr. Canby Balderston, dean of the Wharton School of Commerce of the University of Pennsylvania. Dean Balderston gave a general talk on the general subject of prophecy and planning. Stating that he is an advocate of planning ahead for people, for corporations and for national groups he cannot always approve of federal planning on a detailed scale.

Rising prices must be expected at least for another year, the Dean believes. This means, he added, that we must expect another general round of wage increases, or of strikes in support of wage demands.

The meeting this week was the second to be devoted to engineering aspects of the pulp and paper industry by TAPPI, the first having been held last year in Milwaukee. A more general outline of the program that TAPPI has developed is printed on page 71 of this issue.

## Pacific Mills Gives New Powers to Two

VANCOUVER, B. C.—Two Pacific Mills officials, stationed the company's Ocean Falls, division, are assuming increased responsibilities in mill and town site operations, according to recent announcement by Paul E. Cooper, president. P. A. Frattinger, formerly plant engineer, is now assistant to the resident manager, C. W. E. Locke, and will have under his supervision all matters pertaining to construction, plant maintenance, industrial engineering, paper warehousing and shipping. The townsite manager, J. Harold Falls, has had his duties enlarged to include full jurisdiction over all Ocean Falls townsite affairs, including the company's new residential hotel, "Martin Inn," and the community department store.

Mr. Frattinger, a graduate of the University of British Columbia in Mechanical Engineering has spent his entire career in the pulp and paper industry, with the exception of a three-year period during the war. He has been associated with Pacific Mills for more than eight years, both in Vancouver and at Ocean Falls.

He is a skilled small-bore rifle marksman and is one of three British Columbia residents who were awarded Dominion Marksmen Expert Shields during 1946.

Harold Falls, who joined Pacific Mills early in 1947, has been actively engaged in the construction industry for a number of years in the Vancouver area. He was formerly associated with his father, H. P. Falls, Vancouver building contractor. During the war he was attached to the R.C.A.F. as building superintendent at elementary flying schools.

### Middletown Names Grant Civic Association Head

MIDDLETOWN, Ohio — E. E. Grant, president of the Crystal Tissue Company, has been elected president of the Middletown Civic Association. The Association, which administers and supervises the charitable and welfare organizations of the city of Middletown, is supported by contributions of employes and employers in the city, and governed by a board of elected trustees. This organization was one of the earliest community groups to consolidate all welfare work and contributions in one governing body, having been formed in 1923 by a group of public spirited citizens.

Mr. Grant, who is well known for his activities in the paper industry and civic enterprises, such as Junior Achievement, the Y.M.C.A. and Rotary, brings a wealth of executive experience to the new civic responsibility.

C. N. HAGAR, JR.

Technical Director of Diamond Match plants at Plattsburg and Ogdensburg, N. Y.

### Thompson Heads Larger Office For Bulkley Dunton in Newark

NEWARK, N. J. — The expansion of Bulkley, Dunton & Company's service facilities in New Jersey with the enlargement of their Newark office at 155 Washington Street was made publice this week by J. C. Marvin, vice-president. The new office is headed by Robert N, Thompson, who took up his duties as manager on November 1st, following several years as a salesman for the company.

Prior to joining Bulkley, Dunton, Mr. Thompson was associated with the Lathrop Paper Company, Dennison & Sons, and W. D. Harper, Inc., fine papers. He has had a total of about twenty years' experience in the paper and graphic arts field, and his intimate knowledge of paper and printing will enable him to render valuable service to Bulkley, Dunton's rapidly growing list of New Jersey customers.

Mr. Thompson lives with his family in Montclair.

### Sidney Roofing Appoints McGillivray at Vancouver

VANCOUVER, B. C.—A. E. McGillivray has been appointed district sales manager for Vancouver Island by the Sidney Roofing & Paper Company Ltd., Victoria and Vancouver, according to P. W. Field, general sales manager.

Mr. McGillivray joined the company eight years ago and has had extensive and successful experience in all areas of British Columbia. For the past six years he has been a popular representative with wholesalers and dealers on Vancouver Island. In his new position, Mr. McGillivray will have the assistance of J. H. Roy, who has recently joined the sales staff of the firm.

## Westvaco Moves Four Into Bigger Posts

NEW YORK—Promotion of four men to top executive positions in three West Virginia Pulp and Paper Company plants was made public this week. George N. Hoover, Jr., and Ray A. Stocker have been named assistant managers of the Mechanicville, N. Y., plant; Melvin L. McCreary has been advanced to assistant manager of the Williamsburg, Pa., plant; and J. Lynne Ferner has been promoted to general superintendent of the Tyrone, Pa., plant.

At Mechanicville, Mr. Hoover is in charge of production and operations and Mr. Stocker is in charge of administration and personnel.

Mr. Hoover began his career with the company in 1922 as a helper in the beater room at Mechanicville. From 1923 to 1928 he worked on the paper machines and in 1928 he was promoted to boss machine tender. He was advanced to superintendent of the paper mill in 1936 and in 1946 was named general superintendent of the pulp and paper mills, a position he occupied until his present appointment.

Mr. Hoover is a member of a family which has been associated with the company since its beginning in 1888. His great uncle, S. N. "Bossy" Miller, was in charge of the company's first paper machine at the Luke, Md., plant in 1892, and his father, George N. Hoover, Sr., once was manager of the Luke plant, assistant manager at Mechanicville and on the staff at the Covington, Va., plant.

Mr. Stocker has been with the company since 1942 and was office manager when appointed to his new post. Before coming to the Mechanicville plant he was secretary of the Troy Buick Company, Inc., of Troy, N. Y. Earlier he was associated with several Eastern firms and had been assistant treasurer of the Tolhurst Division of American Machine and Metals, Inc., of Troy.

Mr. McCreary was first employed at the Williamsburg plant following his graduation from Juniata College in 1935, where he received a B.S. degree in chemistry. He first served as a chemist in the plant laboratory and pulp mill and for the last few years has been technical assistant to the plant manager.

Mr. Ferner had served more than two years as superintendent of the paper mill at Tyrone before his promotion. He was first employed in the plant control laboratory during the summer months while attending Juniata College. After graduating from Juniata in 1933 with a B.S. degree in chemistry, he returned to the company as a control tester in the main laboratory, and soon was promoted to chemist. In 1936 he became assistant superintendent of the pulp mill and in 1939 was named assistant superintendent of the paper mill.

## Union Bag Buys Into Highland Container

JAMESTOWN, N. C. — William G. Ragsdale, Jr., president of the Highland Container Company, manufacturers of corrugated shipping containers, disclosed late last week that the stockholders of that company at a special meeting on October 9 had unanimously approved an arrangement between the company and Union Bag & Paper Corporation by which Union Bag & Paper becomes a minority stockholder in Highland Container Company and has entered into a contract to furnish Highland Container Company with its requirements of container board.

Mr. Ragsdale stated that the arrangement between the two companies does not result in any change in the officers or management of the Highland Container Company, but that Union Bag & Paper Corporation will be represented on its board of directors.

He stated that because of the scarcity of container board the company had been unable to supply the demands of its customers, and added that under the arrangement with Union Bag & Paper Corporation, Highland Container Company will be able to substantially increase its output.

Mr. Ragsdale said that a further advantage of the connection was the convenient location of Union Bag & Paper Corporation's mill, which is one of the largest and most modern kraft board mills in the country, located at Savannah, Ga.

### Port Edward Cellulose Revises Its Name

VANCOUVER, B. C. — Port Edward Cellulose Company Limited, subsidiary of the Celanese Corporation of America, which will build and operate a textile pulp plant at Port Edward, B. C., has changed its name to Columbia Cellulose Company Limited.

### "Westvaco Inspirations" Wins D.M.A.A. Merit Award

"Westvaco Inspirations for Printers," published by West Virginia Pulp and Paper Company, has received a merit award in the paper manufacturers division of the 1947 Direct Mail Advertising Association competition, it was announced today.

The award was presented to C. P. Elston, company advertising manager, who directs the production of "Inspirations."

This marks the third consecutive year that the publication has received major awards in this competition. In 1945 and 1946 "Inspirations" won the Best of Industry award.

### Panelyte Opens In Minneapolis Territory

NEW YORK — C. R. Mahaney, vice-president of the St. Regis Paper Company and general manager of its Panelyte division, has made known the opening of a new Panelyte district sales office in Minneapolis, at 2016 Seabury Avenue, to serve Panelyte customers in Minneapolis, St. Paul, and the surrounding area. Herbert M. Giefer, who was associated for several years with C. E. Gobeil Company, St. Paul, former sales agents for Panelyte, is in charge as district manager.

Jann P. Nielsen has been appointed as a Panelyte representative in the Detroit district. Mr. Nielsen, who formerly was associated with Woodall Industries, Camfield Manufacturing Company and Capac Plastics, Inc., will make his headquarters in Spring Lake, Mich.

### Port Alberni Seeks Relief From B-S-W Odors

PORT ALBERNI, B. C. — While the Bloedel, Stewart & Welch Company's pulp mill has barely commenced operations, already the local ratepayers' association is lodging objections to the odors resulting from the establishment of the plant. Vincent Rush, president of the Alberni ratepayers, told a recent meeting of a conference he had had with J. Petrie, manager of the pulp mill.

Mr. Petrie said that efforts of research chemists to overcome mill odors had been so far without complete success. He stated that when power was available from the Campbell River project the situation might be partially corrected.

R. L. KUTTER (right) and S. T. WEBER (left) who have been named vice-president-sales manager and assistant sales manager, respectively, by the Black-Clawson Company, Hamilton, Ohio.

## Thilmany Installs New Barker Drum

KAUKAUNA, Wis. — The Thilmany Pulp and Paper Company is planning to install a new barker drum early this month, according to C. R. Seaborne, vice-president in charge of manufacture. The drum is 30 feet long and 10 feet in diameter, and will remove the bark from 10 to 15 cords of wood per hour.

Construction is now in progress on a new 120 inch wide paper machine in the lower mill. The machine and auxiliary equipment are being assembled and the schedule calls for it to be in operation in the first quarter of 1948. The building for housing the machine was completed in April of this year.

Walls of a 170 by 45 foot garage-warehouse in the upper mill yard have been completed and preparations are in progress to erect the steel girders for the roof.

Excavation for the piers for a 40 by 40 foot enclosed truck loading dock in the yard of the upper mill began two weeks ago. Digging through the 8 feet of solid rock for the piers will be done without blasting because of the proximinity of the work to present buildings, according to Robert Greiseen, staff engineer.

The loading dock will be for the use of the asphalt department along with the new asphalt storage tank which went into operation October 18. The tank is 20 feet in diameter by 25 feet in height and provides 60,000 gallons of added storage capacity. Steam heated coils keep the asphalt in liquid condition for pouring.

### Kupfer Bros. Moves

BOSTON—The local office of Kupfer Bros., manufacturers of surface coated papers, gold and silver papers, and imitation tin foil, now at 60 Batterymarch Street, will be at 88 Broad Street on and after November 15.

# FINANCE

## Great Lakes Studies Varied Production

TORONTO—Great Lakes Paper Company, according to its president, Hon. W. Earl Rowe, has been studying, for a year or more, the possibilities of going into the manufacture of other lines and the utilization of more of the wood grown on the extensive timber holdings of the company.

Mr. Rowe has left for Europe to study at first hand the methods employed in Scandinavian countries in utilizating all species of timber resources. He will also study from that point the near and the longer term outlook for the marketing of products.

An unconfirmed report from Fort William this week stated that Great Lakes Paper plans a $10-$12 millions kraft mill addition to its plant there, and that it is expected that the new plant will be ready to operate when power becomes available through the development by Ontario Hydro-Electric Power Commission on the Pine Portage Falls site on the Nipigon River of another great new power plant to keep pace with Northern Ontario's rapidly expanding industrial development.

Company officials said they did not authorize this announcement and the "official" announcement indicated as far as their plans had gone at present.

When Mr. Rowe was asked by *The Financial Post* before leaving for Europe, for more details of the reported expansion plans, his answer was: "The Great Lakes Paper Company, through its officials and technicians, have for a year or more been conducting studies as to the best means of utilizing, as far as possible, all of the species of timber available on the concessions or leases from which its present supply of raw materials for the manufacture of newsprint are being harvested." These studies resulted in the conclusion, Mr. Rowe stated, that the facilities for the production of additional types of pulp should constitute the

*(Continued on page 141)*

## Package Machinery Hits Record Shipment Day

SPRINGFIELD, Mass.—The Package Machinery Company hit an all-time high in daily dollar shipments recently when for the first time in the company's history more than $100,000 worth of machines were shipped out.

For Henry Gensheimer, who in 1913 shipped the first machine from the Package Machinery plant, it was a red-letter day. And in addition to the big $100,000 day, Gensheimer last week prepared for delivery the firm's 15,000th piece of equipment.

Company officials, multiplying the number of their machines in operation times the rate of operation now, estimated that more than one half billion packages a day are wrapped with Package Machinery equipment.

Said President George Mohlman:

"Our business and our place in the industry is exceptionally good. Incoming orders are steadily increasing and it would be impossible to meet this demand if we were not fortunate in being able to purchase our new plant providing increased facilities."

## Rayonier Sales Up By Fifty Per Cent

NEW YORK—Rayonier Incorporated, manufacturer of wood cellulose, reports for the nine months ended September 30, 1947, net sales of $36,746,539, compared with $24,331,917 in the corresponding period of the previous year. Consolidated net profit after all charges, including Federal taxes, was $6,083,795 against $1,866,363 and was equal, after preferred dividends, to $5.18 per share on the common stock compared with $.93 for the first three quarters in 1946.

President Bartsch states in his letter to stockholders that there is every indication that the favorable operating results during the first nine months will continue. He adds that a dividend of 50 cents per share of common stock recently was paid for the last half of 1947, and says it is expected that early in 1948 the common stock will be placed on a regular quarterly dividend basis.

## Eagle A Earnings Run Ahead of 1946 Showing

HOLYOKE, Mass. — The American Writing Paper Corp., Inc., earned $465,873 in the first nine months of this year, after all expenses including provision for federal income taxes. For the corresponding period in 1946, the net profit for Eagle A was $165,365.

The American Writing Paper has steadily run ahead in earnings this year over a year ago. In the third quarter the profits were $92,245 compared to $42,305 in the third quarter of 1946.

## FINANCIAL RECORD OF THE WEEK

### New York Stock Exchange

High, Low and Last for Week Ending October 31, 1947

STOCKS

| | High | Low | Last |
|---|---|---|---|
| A. P. W. | 5⅞ | 5 | 5½ |
| Armstrong Cork Co. | 52 | 51¼ | 51½ |
| Armstrong Cork Co., pf. | 100 | 100 | 100 |
| Celotex Corp. | 28⅞ | 27¼ | 28 |
| Celotex Corp., pf. | 20⅝ | 20⅜ | 20⅜ |
| Certain-Teed Products Corp. | 19⅛ | 17⅞ | 18⅛ |
| Certain-Teed Products Corp., pf. | .... | .... | .... |
| Champion Paper & Fibre Co. | 25 | 23⅝ | 23⅝ |
| Champion Paper & Fibre Co., pf. | 106 | 105½ | 105½ |
| Congoleum Nairn Co. | 31½ | 30½ | 31 |
| Container Corp. of America | 45⅛ | 43¾ | 44 |
| Container Corp. of America, pf. | 100½ | 97½ | 97½ |
| Crown Zellerbach Co. | 33 | 32⅛ | 32¼ |
| Crown Zellerbach Co., pf. 4.20 | 102⅛ | 100¾ | 102⅛ |
| Crown Zellerbach Co., 4 pf. 4 | 121 | 120 | 120 |
| Dixie Cup Co. | 40 | 40 | 40 |
| Dixie Cup Co., A | 55¾ | 54⅛ | 54½ |
| Flintkote Co. | 38 | 35¾ | 36½ |
| Flintkote Co., pf. | 106½ | 105 | 105 |
| Robert Gair | 10½ | 9⅜ | 9¾ |
| Robert Gair, pf. | 19⅞ | 19⅞ | 19⅞ |
| International Paper Co. | 58 | 54½ | 56⅜ |
| International Paper Co., pf. | 100¾ | 100 | 100 |
| Johns-Manville Corp. | 45 | 42¾ | 43⅜ |
| Johns-Manville Corp., pf. | 121 | 121 | 121 |
| Kimberly-Clark Corp. | 24⅝ | 24 | 24⅛ |
| Kimberly-Clark Corp., pf. | 109¼ | 108¼ | 108¾ |
| Mac Andrews & Forbes | 38½ | 37¾ | 37¾ |
| Mac Andrews & Forbes, pf. | .... | .... | .... |
| Marathon Corp. | 22¾ | 22⅛ | 22⅜ |
| Mead Corp. | 23½ | 21⅝ | 22 |
| Mead Corp., pf. 4¼ | 93½ | 92 | 92½ |
| Mead Corp., pf. 2 | 48½ | 47¼ | 47¾ |
| National Container Corp. | 15 | 14⅜ | 14⅜ |
| Paraffine Companies, Inc. | 72 | 71 | 71½ |
| Paraffine Companies, Inc., pf. | .... | .... | .... |
| Rayonier, Inc. | 28¾ | 26¾ | 28¾ |
| Rayonier, Inc., pf. | 37 | 36¼ | 36¼ |
| Ruberoid Co. | 67 | 64½ | 64½ |
| St. Regis Paper Co. | 11¾ | 11 | 11⅜ |
| St. Regis Paper Co., pf. | 92 | 90½ | 90½ |
| Scott Paper Co. | 46¼ | 45 | 46½ |
| Scott Paper Co., pf. | 98 | 97½ | 97½ |
| Sutherland Paper Co. | 42¼ | 42½ | 42½ |
| Union Bag & Paper Corp. | 35¼ | 33¾ | 34⅜ |
| United Paperboard Co. | 16½ | 15¾ | 15¾ |
| United Wallpaper | 7¼ | 6¾ | 6⅞ |
| United Wallpaper, pf. | 42⅜ | 42⅛ | 42⅛ |
| U. S. Gypsum Co. | 105 | 103¼ | 105 |
| U. S. Gypsum Co., pf. | 180 | 180 | 180 |
| West Virginia Pulp & Paper Co. | 46¼ | 44½ | 44½ |
| West Virginia Pulp & Paper Co., pf. | 111¼ | 111¾ | 111¼ |

BONDS

| | | | |
|---|---|---|---|
| Celotex Corp., 3¼s '60 | 102¾ | 102½ | 102½ |
| Certain-Teed Products Corp., 5½s '53 | .... | .... | .... |
| Champion Paper & Fibre Co., 3s '65 | .... | .... | .... |
| Mead Corp., 3s '68 | .... | .... | .... |

### New York Curb Exchange

High, Low and Last for Week Ending October 31, 1947

STOCKS

| | High | Low | Last |
|---|---|---|---|
| Great Northern Paper Co. | 46½ | 44 | 44 |
| Taggart Corp. | 10½ | 10½ | 10½ |

BONDS

| | | | |
|---|---|---|---|
| American Writing Paper Co., 6s '61 | 102 | 102 | 102 |

## Mexico Expands Its Paper Production

WASHINGTON — The Mexican paper industry expects to show an output of 138,768 tons of paper and paperboard for 1947, according to estimates forwarded to the Department of Commerce.

To attain this production, approximately 117,695 tons of all types of pulp will be consumed, of which 60,895 tons must be imported.

Contributing largely to production this year is the output of unbleached sulphate pulp of the new kraft paper mill at Atenquique, Jalisco, which recently came into operation. There is some doubt expressed, however, if this new mill can attain the estimated annual production capacity of 26,400 reported earlier.

Last year, with pulp supplies at lowest level since 1940 for both the United States and Mexico, the latter country obtained much of its chemical pulp from Canada, Sweden, and other foreign sources. The only imports of groundwood pulp last year were from Norway, 94 tons.

Competition from the Mexican paper industry is not expected to assume important proportions in the immediate future, it is stated. Production usually is confined to cruder types of paper and paperboard. The finer qualities obtainable from the United States will continue to be imported even should domestic output match the demand, it is believed. Antiquated machinery and obsolete manufacturing methods are said to be handicaps to the local production plans. Some used equipment is being added, it is reported, but an exception to these conditions is the new mill in Jalisco, just mentioned, which is entirely modern. Furthermore, two other mills are under construction, one for manufacture of high-grade cigarette and other tissue papers, and the other, for facial and sanitary tissues.

The Jalisco mill may be able to supply Mexico's demand for kraft paper, it is said, and the two mills now being completed may eliminate import requirements for the specialties they will manufacture, or at least, meet any deficiency not supplied by imports.

Present demand is said to be so great, however, for both domestic and imported paper and paperboard, that United States manufacturers and exporters do not need to worry over present competition, and unless prices rise too greatly, competition from European and other foreign sources will not be important, according to this source.

The Mexican market is described as "a good market for United States papers."

The general increase in business activities in the past 5 years, as well as changing demands, has called for more paper for office forms, records, correspondence, advertising circulars and other business uses, besides an augmented demand for containers, wrapping papers and other industrial uses. Larger quantities of newsprint, writing paper, and bookpapers are being called for, it was reported.

The demand is essentially unchanged from the war period, exceeding supply, and with the United States as the leading source. The trade reported that if supplies had been available, total consumption probably would have attained 250,000 tons. Changing conditions do not permit an exact estimate of requirements, but some sources quoted said that Mexico requires approximately 30,000 tons annually of imported paper and paperboard, excluding newsprint, kraft, other coarse wrapping papers, cigarette paper or wallboard.

Newsprint importation last year amounted to 55,923 tons. The printing and lithographing industry accounts for the biggest use of paper. Other markets include paperboard containers, folding and set-up boxes, Mexican tastes are changing, putting increased emphasis on sanitary wrappings, special packaging, etc., and in other packaging, consumption of paper bags and shipping sacks has reached an estimated 10,000 tons annually, 85 percent of which is grocery bags. Paper shipping sacks are replacing cotton bags for lime, plaster, etc. Among other products, the textile industry uses fiber cans, with the 9-inch diameter required for British machinery is greatest demand, though the 12-inch can also is required, for U.S.-made machinery. The cans are imported in parts, for assembly in Mexico, imports being entirely from the United States.

Paper cups, liquid-tight containers and drinking straws are coming into increased use, also. There is a demand for waxed paper, with prospects for U.S.-manufactured paper good, it was reported.

### Snyder Tells Superintendents About Jacketed Steel Dryers

SPRINGFIELD, Mass. — The annual meeting of the Connecticut Valley Division of the American Pulp and Paper Mill Superintendents' Association was held at the Hotel Sheraton here. George L. Snyder, assistant manager of the developing and engineering department of the Lukens Steel Company discussed "Jacketed Steel Drier Rolls for More Production."

### YMCA Honors Charles Kay

VANCOUVER, B. C.—Charles J. Kay, founder of the Columbia Paper Company and winner of the Good Citizen Award in 1941, received a new honor recently when the new YMCA chapel, part of a $100,000 addition to the plant at Vancouver, was dedicated to him and will in future be known as the Charles J. Kay Chapel. The chapel was named in recognition of Mr. Kay's 23 years of service as a lay worker and benefactor of the YMCA.

## Masonite Process to Enter South Africa

CHICAGO — Eugene Holland, president of Masonite Corporation, reported last week that a plant using the Masonite process for making wood fiber hardboards and insulation boards is under construction at Estcourt, Natal, Union of South Africa. The cornerstone was laid recently, and the factory is expected to start operations next year.

The plant is being built by Masonite Africa, Ltd., in which Masonite Corporation owns a substantial stock interest. Mr. Holland said Masonite bought part of its common stock interest in the African company and accepted the remainder in payment for engineering services and trade-mark rights in the Union of South Africa.

Mr. Holland pointed out that this acquisition brings to three the number of foreign companies owned in part by Masonite Corporation. The others are Masonite Corporation (Australia), Ltd., and Masonite Company of Canada, Ltd.

The former has had a plant in successful operation since 1938 near Newcastle, New South Wales, and its original production capacity was doubled in the last year. The Canadian company also has a similar plant expansion program under way at Gatineau, Quebec, where operations were started in 1940.

Two other foreign companies, one operating in Sweden and the other in Italy, use the Masonite process under license agreements.

### Atlantic Carton Plans $3 Million Improvements

NORWICH, Conn.—Plans for a three million dollar plant expansion and improvement program by the Atlantic Carton Company are now under way. Completion of the whole project which will result in an increase of about 300 employes will probably take about a year.

The Atlantic Carton Company acquired the National Pairpoint Company at New Bedford, Mass., recently and plans call for the removal of that business to Norwich.

The National Pairpoint Company is engaged in the production of paper used in the folding cartons made by Atlantic. Some of the paper-making machines are 300 feet long and consequently take up large floor areas. The Atlantic plant in Norwich will be practically doubled in size. A new power plant will be built and to arrange a smooth flow of materials the existing plant will practically be rebuilt.

Production operations cannot be interrupted because of heavy container requirements. The folded container packages for food, drug and hardware trades made by Atlantic Carton Company are used by a number of national concerns.

## Union Bag Sees Rise In Tall Oil Output

NEW YORK—United States capacity for the production of tall oil is expected to hit an all-time high in 1947 of 125,000 to 130,000 tons, according to officials of Union Bag & Paper Corporation, who cite the figure as an example of the steady progress being made by the kraft industry in utilizing former residue products of paper making.

Tall oil, raw material for paints, insecticides, soap, emulsifiers, disinfectants, and various forms of lubricating and cutting oils, is being produced in volume quantities at Union Bag's plant in Savannah, Ga.

"Paper mills are only now beginning to do what coke manufacturers did 50 years ago when they began to recover the many values of coal, which in the old method of coke-making were volatilized and wasted," a company official said. "In the future paper mills may really become chemical plants and it is possible that their chemical products may in time have more commercial value per ton than the pulp itself. This is one of the big undeveloped raw material fields in industry today and tall oil is but one example."

Tall oil is one of the lowest priced fatty materials on the market, officials point out. Refined tall oil is selling at around 5¾ cents per pound and even after the addition of reagents, the cost of the esterified product is considerably less than the price of materials with which is competes.

Refined tall oil, combined with various reagents, performs the same functions as other oils—such as linseed, in the manufacture of paints and varnishes—at about half the cost. It is also widely used in making many types of soap, emulsifiers, insecticides, and disinfectants, in metal processing, in cutting and lubricating oils, core oils, textile processing oils, and other industrial products.

In its crude state it also has many valuable commercial uses where color and odor are not a factor. It is used as a flotation reagent in the concentration of ore; as an emulsifier or additive in asphalt road construction; in the manufacture of low-priced soap for industrial cleaning; in making linoleum, and other uses.

In recovering tall oil from the sulphate process of paper making, the industry is recovering a product which as recently as 15 years ago in the United States was a loss except for fuel value.

The recovery process was first developed in Sweden about 30 years ago, and not used to any extent in this country until the middle 1930s. In 1937, just a decade ago, the entire United States production of tall oil totaled about 10,000 tons, as compared with this year's estimated 125,000 tons.

Occurring naturally in the wood are fatty acids and resin acids. In kraft pulping, which is an alkaline process, these acids are saponified by the alkali to a soap which can be skimmed off of the spent cooking liquor. This material known as "soap skimmings" is then cooked with acid to obtain crude tall oil. The yield of crude tall oil is from 70 to 90 pounds per ton of pulp depending upon the species of wood and certain other factors. It is estimated that about 35 to 45 tons of crude material a day can be recovered by a plant with a capacity of 1,000 tons of pulp per day.

Officials of Union Bag & Paper point out that it requires 4,500 pounds of wood to make one ton of paper, more than half of the original material being lost in the process. The recovery of tall oil is one of the first steps in utilizing the wastes in sulphate paper making.

### Sangamon Mills Promotes Russell and Miller

CHICAGO — T. J. Russell has been promoted to be assistant to the president, and Homer J. Miller to be general manager of the Sangamon Paper Mills. Mr. Russell has been with the company since its inception, starting as superintendent. Mr. Miller was formerly with the Container Corporation of America for many years. Both men are well known to the trade.

Sangamon's mill at Eaton, Ind., is going through a modernization and expansion program, which is to be completed by April, 1948. After completion, the plant will have a seven cylinder machine, trimming 82 inches, and will manufacture test liner board, highgrade boxboards, chipboard, and cylinder specialties, with a capacity of 150,000 pounds per twenty-four hours.

### Shane Joins St. Regis In Public Relations

NEW YORK — Samuel Shane, formerly with the *Wall Street Journal*, has joined the St. Regis Paper Company. Mr. Shane, who covered the pulp and paper and publishing industries for the *Journal*, was previously for ten years financial editor of the Montreal *Gazette*. Mr. Shane will be engaged in public relations work in behalf or the St. Regis Paper Company, St. Regis Sales Corporation and St. Regis Paper Company (Canada) Ltd. He will be a member of the staff of Kenneth D. Lozier, vice-president, St. Regis Sales Corporation.

### Tufts Elects Spaulding To Finance Committee

BOSTON — Huntley N. Spaulding, president of the Spaulding Fibre Co., Rochester, N. H., and Tonawanda, N. Y., was elected a member of the finance committee of Tufts College at the annual meeting of the board of trustees at the Parker House, October 30.

## Foresters Society Meets in December

MINNEAPOLIS, Minn. — The annual meeting of the Society of American Foresters, an organization of professionally educated foresters with headquarters in Washington, D. C., will be held December 17-20 at the Nicollet Hotel. An attendance of 500 members and guests is anticipated.

According to S. W. Allen of Ann Arbor, Mich., president of the Society, the national assembly will open on December 17 with an all-day conference of the Society's Division of Education, and a meeting of the Society's Council, the organization's governing body, with the officers of its 21 sections.

On December 18 will be held seven individual sessions of subject divisions devoted to private forestry, forest economics, forest recreation, forest products, wildlife management, range management, and silviculture. Nonmembers interested in these fields of specialization are welcome to attend.

The general sessions which start December 19 and continue through the morning of December 20 will feature technical papers and discussion of the progress of private forestry in the Lake States. On the evening of December 19 the Society's annual dinner for members, their ladies, and guests will be served in the ballroom of the Nicollet Hotel.

Organized in 1900, the Society of American Foresters has a membership of 5,500 practicing technicians in the United States and Canada.

### Michigan Superintendents To Meet November 20

KALAMAZOO — The November meeting of the Michigan Division of the Superintendents Association will be held at the Park-American Hotel, Kalamazoo, on the 20th at 6:30 p.m. In conjunction with this meeting, the General Electric Company will have an electrical exhibit in the basement of the hotel on the 19th and 20th.

There will be a speaker at the dinner. His subject will be "The Regulation of Speed, Voltages and other Vital Characteristics by Electronics and Other Means" together with a talk by W. W. Chronkhite, commercial consultant, Industrial Manufacturers Division General Electric Co., Schenectady, N. Y.

The group is extending a special invitation to the Chief Engineers Club of Kalamazoo Valley and all engineers interested in electrical developments.

### Hardy on St. Croix Board

WOODLAND, Me. — John A. Hardy, son of the late George F. Hardy, has been elected to the board of directors of the St. Croix Paper Company, assuming the place made vacant by his father's death.

# The TAPPI Fall Meetings

By R. G. Macdonald, Secretary-Treasurer
Technical Association of the Pulp and Paper Industry

For many years it was the practice of the Technical Association of the Pulp and Paper Industry to hold two national meetings each year. One was and still is held in February, and is designated as the annual meeting. The so-called fall meeting was held in September or October at some location other than New York.

Over the years the annual meeting has attained great prestige and it is common practice to refer to the time of this meeting in New York as Paper Week. At the same time that this meeting is held there are meetings of the American Paper and Pulp Association and a large number of affiliated organizations. For several years the National Paper Trade Association met during this week but recently this group has been meeting later in the spring.

Because of its prestige the annual meeting of the Technical Association has attracted most of the original papers offered by its members. It is expected, however, that with the growing prestige of the new type of TAPPI fall meetings that the annual meeting will not be able to retain its monopoly of the highest quality papers.

Until the recent war the fall meetings of the Association have, for the most part, been held in pulp and papermaking centers such as Green Bay, Kalamazoo, Richmond, Syracuse, Savannah and Holyoke, and at West Coast centers such as Portland and Seattle. For many years the attendance at such meetings was under 800 and because of the breadth of interest of those attending the programs were general in nature, an effort being made to feature local industries.

The earlier fall meetings usually provided for mill visits and an interesting social program. The first fall meeting with an attendance in excess of 1000 was held in Savannah, Ga., in 1937 when 1200 attended. Thereafter the attendance was in the neighborhood of 1000.

The approach of the war emphasized the need for more serious and more highly specialized meetings. This was reflected in the 1942 meeting in Boston when great emphasis was given to the subject of packaging and packaging materials. At this meeting the branches of the Army Service Forces were first represented, and in the following year the meeting at Chicago represented an all-out effort to mobilize the industry to deal with the war effort.

The Chicago meeting was a tremendous affair. More than 4200 attended and a 20,000 square foot exhibit was provided by all of the Army and Navy service branches to demonstrate the magnitude of their packaging problems. The program itself was extraordinarily glamorous with the Services being represented by admirals, generals, and a large number of staff officers. To make the meeting particularly effective 1500 Army and Navy packaging contractors were invited and more than this number attended. This was considered to be an outstanding opportunity by the major military Services since the entire problem of packaging hundreds of thousands of materials was in somewhat of a muddle and thousands of man-hours were being expended by the Service forces in explaining their specifications and in teaching contractors how to package materials.

The field of packaging and packaging materials itself was going through a revolutionary process and there was general bewilderment. The Chicago meeting of TAPPI did much to solve this important problem and was one of the contributions that later led the Navy Department to present the Certificate of Achievement to the Technical Association.

Following the Chicago meeting the national problem of transportation led to the holiday during which all organizations were requested to hold no conventions. The main object was to release transportation equipment for the use of troops and essential materials.

In 1946 it became possible again to hold meetings although the railroad situation had not greatly improved and accommodations in nearly all hotels were at a premium. To meet this limitation of available hotel rooms it was decided by the Technical Association to hold a few meetings that would attract a relatively small number of members.

It was further decided to organize these meetings on a functional basis and to attempt to perform a thorough survey of certain limited subjects. Meetings were planned for Detroit, Milwaukee, and New Orleans, these cities being selected because of their size and hotel availability.

The Detroit meeting was organized primarily for the industry's management and was sponsored by the Funda-

TAPPI Meets at Alton, Ill.;—under auspices of The Fibrous Agricultural Residues Committee

mental Research Committee. This dealt with the "Sources, Procurement and Utilization of Pulpwood." The subject was selected because of the evident need to make a thorough inventory of the pulpwood supply of the nation and to consider the economies involved in its procurement and complete utilization. This meeting was an outstanding success from the standpoint of the papers presented. Because of this the material presented was later incorporated in an Association monograph on Pulpwood which is considered to be the best document of its kind that has been published.

### Milwaukee Inaugurated New Effort

The Milwaukee meeting represented a new effort on the part of the Association. At the time G. W. E. Nicholson of the Union Bag & Paper Corporation was president of the Association and had as one of his objectives the establishment of a strong engineering division in the Association. Although the Association was originally organized as an engineering group the tremendous influx of chemists and chemical engineers into the industry during the period between the wars had resulted in a domination of the Association's program by research and other technical men. This was a natural development since the industry was expanding rapidly and the need for modernization and efficient mass production offered a tremendous opportunity to the chemical engineer.

Meanwhile the engineers of the industry carried on their fine work but did not attend or participate to any great extent in the national meetings of the Association. It became evident that there was a growing need for the plant engineers to get together. There was a tremendous postwar expansion ahead with new and improved equipment and materials to work with.

It was not surprising, therefore, that there was an immediate response from the industry when the First Engineering Conference of the Pulp and Paper Industry was announced to be held at Milwaukee. Although accommodations made it necessary to restrict attendance, the leading engineers in the paper industry of Canada and the United States were able to attend. The program which was based on some of the observed major problems of the industry was an unusually fine one and as a result the success of the meeting established it as the first of the annual conferences which will be held over future years. The Second Engineering Conference was held at Philadelphia this week. A feature of both of these conferences has been visits to the plants of machine builders and other equipment firms.

The rapid growth of the kraft industry in the south provided opportunity for the Association to render another specific service. Prior to the railroad holiday such a meeting had been held at Savannah, and its serious consideration of certain operating problems and open discussion of matters that previously had been considered to be somewhat secret, immediately gave the meeting a high standing in the minds of those who attended.

The need and desire for future meetings of this type was apparent and as a result the Gaylord Container Corporation invited the Alkaline Pulping Committee and the Chemical Products Committee to sponsor a similar meeting at New Orleans at a future date with the Gaylord Container Corporation acting as the host. In 1946 this meeting was held and very thorough consideration was given to the methods used in brown stock washing. The degree of specialization and complete treatment of a subject such as this met with general approval.

This year these committees were invited by the Champion Paper & Fiber Company to hold their meeting at Asheville, N. C. This invitation was also extended by the Ecusta Paper Company and by both companies to the Southern and Southeastern Divisions of the Superintendents Association. Although the meetings of the two groups were held separately, the mill visits and the social programs were joint affairs.

The smaller meetings seem to offer much more of value to those who attend. There appears to be greater informality and the managements of the various mills tend to support the small, highly objective meetings more, both with their own presence and by sending a larger number of plant men to attend.

### 1947 A Busy Year

In addition to the Engineering and Alkaline Pulping meetings held this year there were three other meetings. The Fundamental Research Committee which sponsored the Detroit meeting on pulpwood in 1946 this year sponsored another meeting at Appleton. This was devoted to polysaccharides and lignin and attracted the leading organic chemists of the country who are interested in these branches of chemistry. Again, the treatment of this subject under the direction of Dr. Harry F. Lewis, chairman of the Fundamental Research Committee, led to the preparation of another monograph on the subjects covered at this meeting. If we were talking about slot machines we might say that Dr. Lewis' committee has "hit the jackpot" two years in a row.

Two other committees that have had previous experience in sponsoring specialized meetings held similar meetings this year. The Plastics Committee met at Syracuse, and the Fibrous Agricultural Residues Committee met at Alton, Ill. To say that two committees met might indicate that but a small group was present. It would be better to say that they sponsored conferences since in each case these two committee meetings were attended by more than 100 individuals, all vitally interested in the affairs of the committee and the informative subjects that were discussed.

The Fibrous Agricultural Residues Committee is literally a Division of the Association since its structure covers nearly all phases of manufacture from raw materials procurement to the finished product. In fact, because of the nature of the industry it represents the committee is almost an association in itself. Previous meetings were held in New York and Peoria, Ill. This year the Alton Box Board Company was a generous host and the meeting was featured by plant visits including one to the Alton Box Board Company where the new wide, high-speed seven-cylinder machine was in operation.

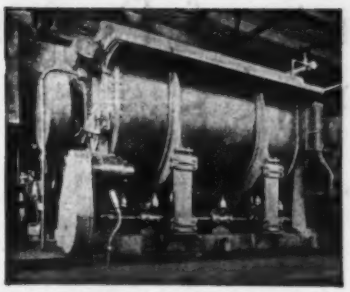
### Future Policy is Elastic

The future policy concerning the type of meetings to be held, aside from the annual meeting is not definite. The small, specialized meetings have proven to be a success but it may be considered desirable to occasionally have a general fall meeting. The cumulative attendance at the 1947 fall meetings has been 1200 or more. How many might have attended a single general meeting is speculative. It might have been more or less than this number. If more, it would present a problem of location since such large numbers can be accommodated in only large city hotels or hotels along the golf circuit. Most of these locations are not near many pulp and paper mills and it is unlikely that intensive programs such as those held at the committee sponsored meetings could be organized.

In 1948 it is at present apparent that small specialized meetings will again be held. The Fundamental Research Committee is working on a program dealing with the physical properties of wood and wood fibers. The Third Engineering Conference of the Pulp and Paper Industry is already scheduled for Buffalo. The Plastics Committee and the Testing Division are considering a meeting at Pittsburgh, and the Fibrous Agricultural Residues Committee and the Alkaline Pulping-Chemical Products Committees are giving thought to their plans for next fall.

Another branch of the industry is getting ready for an international meeting on Mechanical Pulping. This is scheduled to be held next fall at Poland Springs, Maine. John L. Parsons of the Hollingsworth & Whitney Company is endeavoring to organize a program that will justify the publication of another monograph. It is expected that a large number of Canadian mill representatives will attend and participate in the program.

The sulphite pulping industry almost had such a meeting this year but postponed action in consideration of the new developments taking place. Thought is being given to holding such an important conference on the Pacific Coast possibly in 1949. If this is done the whole pulp and paper industry will probably want to get aboard the TAPPI "Special" when it heads into the setting sun.



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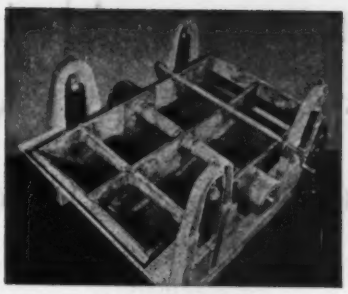

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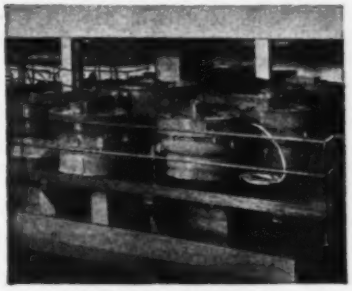

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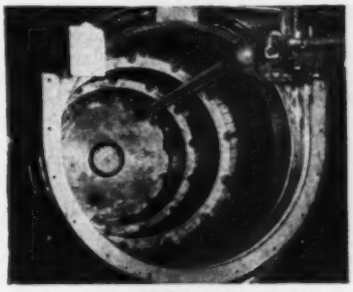

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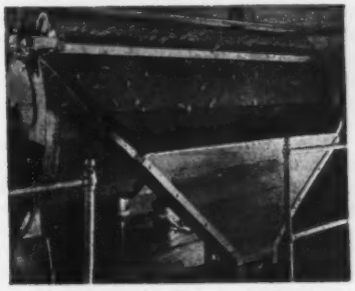

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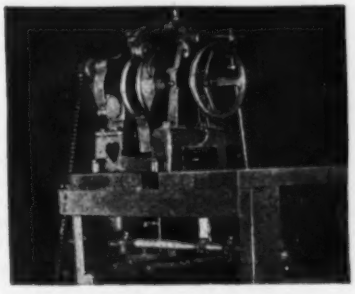

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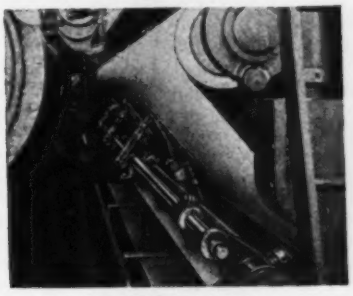

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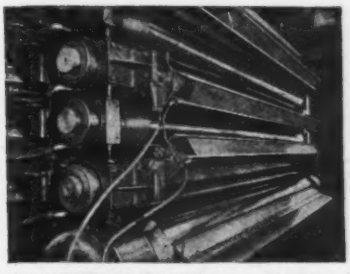

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# Philadelphia Summary Abstracts of Papers Read this Week before TAPPI's Second Engineering Conference

### Treatment of Surface Water Supplies for Pulp and Paper Mills—R. R. Adams, J. E. Sirrine & Co.

The surface waters and the treatment thereof for pulp and paper mill operations in the Southeast are discussed. Because of the varying quality of water in various localities from the Blue Ridge Mountains to the rivers in the coastal regions of the Carolinas, and those in Georgia and Florida, it is necessary to vary the type of treatment to provide waters of suitable quality.

The successive stages used in the treatment of surface waters may be divided as follows: (1) plain sedimentation, (2) sterilization, (3) chemical feeding, (4) chemical mixing, (5) flocculation, (6) sedimentation, (7) filtration, (8) pH correction, (9) clear water storage.

Plain sedimentation is used where the waters are very turbid with a sterilization stage to control bacteria and algae. Alum is generally used as a coagulant with the added addition of an alkali when turbidities are above normal. Two general types of flocculation equipment are used: stationary baffles or mechanical devices, the latter having the advantage of being more adaptable to control. Various types of sedimentation basins and equipment are used before the filtration stage. The rate of filtration may be limited to 2 g.p.m. per square feet if the water is to be used for drinking purpose but rates of 2.5 to 3.0 g.p.m. per square foot are not unusual. pH adjustment before storage completes the system.

### Centralized Planning and Control of Plant Layouts—C. E. Cass, Marathon Corp.

The need for a plant layout program, regardless of plant size, is stressed, and its establishment as a staff function is advocated. This type of organization will minimize the possibility of duplication of effort, make long range planning possible, and will assure the coordination of effort.

The functions of the plant layout department include the analysis and design of layouts for the manufacturing department. A flow chart is essential from which it is possible to determine if various stages in the operations can be eliminated, combined, sequence changed, or simplified.

The master layouts can be made by using a flat plane with templates which are held in place by superimposing a transparent sheet. Flow lines, conveyors, etc., can be indicated on the sheet, and the whole assembly photostated for permanent record.

A well organized plant layout program will reduce manufacturing cost by providing straight line flow, reducing the amount of work in process, conserving floor space, and improving handling methods.

### Reminiscences of the Pulpwood Campaign—Case Study in Materials Handling—C. E. Patch, Morton C. Tuttle Co.

This paper opens with some of the almost axiomatic statements applying to all transportation problems; that movement should be in the largest possible units; that loading and unloading should hold the transporting medium idle the shortest possible time; that picking up and setting down a piece of lading, changing direction of movement, storage in process, and changes in unit size along the way all add to transportation cost.

There is a short discussion of some of the cost factors involved in harvesting and handling pulpwood including not only those of wood yard organization and operation, for which the wood yard foremen and employees are responsible, but those of the kind of facilities provided, and the purchasing and inventory policies set by the management or imposed by conditions.

Following this is a review of observations of many wood yard situations made by an engineer who is not a paper mill employee but is connected with a construction company which has done a large amount of paper mill building both north and south. These reminiscences are illustrated with slides made from sketches and snapshots made by the writer. Side lights are contributed from the pineapple and sugar industries of Hawaii.

### Heating Water with Waste Heat—L. G. Janett, J. O. Ross Engineering Corp.

Methods of recovery of heat from paper machine exhaust air to heat white water, fresh water, or mill supply have been used over a period of time sufficient to yield data for evaluation of returns.

Study of possible uses for the heated water is of prime importance in exploring the possibilities for heat recovery. In geographical areas where seasonal water supply temperature fluctuate widely, more uniformity of water temperatures on the wet end of the paper machine are desirable from a paper quality standpoint. Any water usage requiring direct heating with steam is a potential application for hot water from a recovery system.

Actual operating data are stressed with the presentation of tabulated data and graphical illustrations of water quantities heated, temperature rises, and resultant b.t.u. recovery totals.

Various methods of heating water are described including vertical and horizontal spray systems, centrifugal scrubber type air washers, and Briner economizer water contacting surfaces.

A resume of data on one board mill installation indicates heating a large volume of mill supply water from an initial yearly average water temperature of 59.4°F. to a final yearly average water temperature of 101.3°F. This particular installation showed a yearly steam saving of approximately $8,930 using an average steam cost of $0.338 per thousand pounds of steam.

The efficiency of any recovery system is affected by the quality of the paper machine exhaust air. Well hooded machines operating with high steam pressures in the driers usually have exhaust air with higher absolute moisture content and total heat content than machines operating at low steam pressures. The variables of air quantity and quality between machines operating under widely different conditions necessitates considerable compilation of empirical data to arrive at rational design of water heating equipment.

A summation of the experiences from a group of installations results in establishment of a number of general minimum requirements that should be met in order to justify installation of water heating apparatus. These can be set down under the headings (1) usable heated water quantities, (2) air volumes exhausted from individual paper machines, (3) heat content of exhaust from paper machines, (4) steam costs, and (5) general machine room adaptability features for equipment installation.

### Steam Supply and Control Arrangements for Driers—G. H. Young, Midwest Fulton Machine Co.

An illustrated discussion of various steam supply and control arrangements for driers, which have proven practical and workable with remarks on piping systems.

### Systematic Operation of Construction and Maintenance Departments—Lee C. Dryden, Marathon Corp.

This is the description of the control of construction and maintenance departments through the use of a dispatcher and some rather simple forms for work orders, machine and equipment and building history cards.

Request for work to be done by these departments will be channeled through the single function of the dispatcher. The dispatcher will issue all work orders to crew chiefs or group leaders of the trades and crafts of the construction and maintenance departments. After work is completed the work orders are returned to the dispatcher who records the results and cause on the proper history card and then forwards the work orders to the plant engineer for final processing.

The benefits to be derived from this type of control are summarized in this discussion.

### Paper Mill Lubrication—Drier Bearing Circulation Systems—A. I. Sippola, Socony-Vacuum Oil Co., Inc.

Approach to the circulation method of lubrication was by use of the ring-, chain-, and collar-oiled bearing. To minimize oxidation in this type bearing, oil was removed from the heat zone by continuous feed and overflow return. Providing still more oil to each bearing permitted the elimination of ring, chain or collar. This in turn permitted the elimination of the overflow principle, allowing all the oil to drain from the bottom of the bearing housing. This dry-sump principle of operation has been extended to antifriction bearings as well.

Heat, paper fly, and moisture are threats to correct lubrication. In new machines, contamination occurs during erection. This may be soluble or insoluble and necessitates proper flushing out of the system.

The newer machines, with improved bearing seals, have made it possible to further increase the rate of oil flow, and thus provide lower temperature of the oil as it leaves the bearing, and improved mechanical washing. With increased rates of oil flow, 5000 to 8000 gallon systems are not unusual. The capacity should be sufficient to allow complete recirculation in 1 to 2 hours. The size of oil feed and return lines has been increased to permit adequate flow. Water or moisture contamination is combatted by proper venting, by use of exhaust blowers, or by introducing enough cool air to maintain 1 to 2 inches of mercury pressure within the system.

As circulation systems came into use, accumulation of deposits causing line stoppages, and deposit formations within bearing housings, were encountered. Circulating oils were not always the best, thus accelerating deposit formation. Improved lubricating oils were required and those available today possess very high chemical stability and will minimize rusting.

In old-type systems, the oil-recycling time is very short. Bearings may be lubricated in series, and due to high temperatures the oil will be subjected to severe oxidation. In series oiling, following bearings depend on flow from the first, and therefore individual bearing oiling is preferred. Oil lines from the bearing may be too small. Goose-necks or traps may exist where insoluble materials may cause plugging and subject the oil to elevated temperatures. Overhead gravity tanks, used on older systems, provide comparatively low oil pressure at the sight-feed oilers, and because of the low pressure, contamination can cause plugging at this point. Bearings without seals may allow oil leakage and entrance of contaminants.

In the present-day circulation systems, larger capacities are necessary because each point of application is individually supplied from the main header. Greater flow results from an increased number of applications, since each bearing is separately oiled. Builders now provide bearing housings with small journal clearances and multiple oil-sealing grooves, thus eliminating felt seals.

Despite improved machine design and improved oils, it is necessary to inspect machine elements, as well as to analyze the oil, in order to determine the true condition of the system.

### Installing and Maintaining Flow Meters in Pulp and Paper Mills—C. H. Barnard, Bailey Meter Company

The value of flow meters can be greatly increased if the installation and maintenance are such that maximum accuracy is obtained.

Initial accuracy is largely dependent on the installation, and care should be taken that the primary element is installed where sufficient lengths of pipe exist, where the connecting piping will slope in the proper direction, and where abnormal conditions will not harm the meter.

The best installation comes from good workmanship, and care should be taken to comply with the manufacturer's recommendations when installing the equipment.

Meters for steam, water, gas, air and other fluids have different requirements, and each should be considered from many standpoints to get the best possible answer.

Accessories to assist in keeping the meter clean and active should be installed when fluids with special characteristics are to be metered.

The sustained accuracy of a meter depends on proper and adequate maintenance, and a properly established instrument department within a plant should arrange its activities to provide the necessary care. The department can also assist in the purchase of new equipment, development of special application, supervise installations, and stocking of spare parts in addition to providing routine and emergency service.

Manufacturers of meters maintain staffs of field engineers for service and consultation purposes, and some manufacturers offer instrumentation courses. Advantage should be taken of these services to the greatest possible extent.

The measurement of heavy black liquor flow can now be handled successfully by a bellows operated electronic telemeter, or by the newer Area telemeter. Both provide many advantages over other types of meters for this service, and will give an accurate reading with long, trouble-free life.

### The Suction Roll of Today — H. C. Merritt, Downingtown Manufacturing Co.

The basic design of suction rolls was fairly well known, however, problems involved in their manufacture hindered their development. With increased paper machine speeds, they became more desirable and roll manufacturers were induced to solve the problems and produce a direct driven roll with a noncorrosive shell having a rubber cover with holes properly spaced for maximum water removal.

The suction couch, primary suction couch, suction drum rolls, suction extractor roll, suction press roll installations have contributed to more efficient water removal, and consequently higher speeds, with an increase in wire and felt life. These suction units are described briefly.

### Short Circuit Analysis of a 40,000 K.V.A., 2300 Volt Power System on an "A.C. Network Calculator"—E. L. Cowan and W. V. Knight, Gaylord Container Corp.

Regardless of the thoroughness of design, construction, and maintenance, an electric system will occasionally be subjected to faults or short circuits. The factors that contribute to the magnitude of short circuit currents are outlined and a description is given of an A.C. Network Calculator.

The network calculator is a miniature power system in which actual, or contemplated electrical networks, can be set up in small scale to permit the study and analysis of operating or design problems. Very small impedances, selected in direct proportion to actual impedances, are used to represent generators, motors, transformers, cables, etc., and are interconnected to simulate the distribution system. Meters give values which can be directly related to the actual installation by use of a factor when short circuits are applied to any part of the system. The use of this equipment has resulted in much information that has indicated methods of improvement which possibly would not have been apparent by any other means.

### A Fuel Engineering Study of Some Recent Boiler Installations in the Pulp and Paper Industry—J. E. Tobey, Fairmont Coal Bureau

New postwar power plants reflect improved design with respect to fuel-burning equipment. Results of a comprehensive study of the design specifications of 65 postwar boiler units purchased by the pulp and paper industry in the Northeastern industrial area, ranging in capacity from 200,000 down to 6,000 pounds of steam per hour, are reported.

The economics of conservative design, and flexibility in new steam-generating equipment are stressed.

The future fuels outlook in the United States, with special reference to coal quality, is discussed. Buyers are urged to carefully study fuel requirements to determine which coal fields can best meet their long-range plans.

The author recommends that design of new installations should be preceded and based on a comprehensive study of fuels which will logically be available for the life of the plant.

### Preventative Maintenance — G. W. Charters, Crown Zellerbach Corp.

Preventative maintenance is consciously organized and preplanned prevention of lost time of productive units. While maintenance is a service department, it is no less important than so-called production personnel. Maintenance must be given the same status and rank as production if it is to achieve the objective for which it is created.

Preventative maintenance as contrasted to plain "maintenance" puts the emphasis on "fixing" before natural wear and tear result in loss of scheduled production time. Our contention is that preventative maintenance costs less than plain maintenance.

#### Organization Structure for Maintenance

On a normal basis all maintenance work, both mechanical and electrical, should head up under one person, the plant engineer, or, if the plant or engineering work is large enough, to an assistant plant engineer. Under the man heading up all maintenance, there should be a mechanical superintendent, a chief electrical engineer, and the chief power plant engineer.

All maintenance personnel, regardless of where assigned, should be part of the maintenance organization. Where necessary, maintenance personnel should be permanently assigned to specific departments, but should continue to be part of the maintenance organization. To the greatest extent possible maintenance personnel should be pooled and made available wherever needed only for the time they are needed. The necessary first hand acquaintance with equipment and specific operation under this pooled maintenance plan can be provided by having one or more permanently assigned millwrights or other maintenance persons in each department.

Developing and maintaining the proper organization for maintenance requires written assignment of duties and responsibilities and the reduction to written standard practices of all recurring matters.

An essential part of preventive maintenance are mechanical and electrical inspectors reporting to the mechanical and electrical superintendents.

#### Measurement of Maintenance Effectiveness

The aim of maintenance is to prevent loss of scheduled production time. In order to tell the man heading up maintenance how well he is doing and to encourage and stimulate the maintenance personnel, some method of measurement of effectiveness is necessary. A system of doing this has been developed and successfully operated for a number of years.

#### Techniques of Maintenance

Given an objective, an organization, and a job to do, maintenance must develop certain techniques or patterns. Insofar as these patterns can be routinized, they could be, and should be reduced to written standard practice. A number of such patterns have been standardized and will be explained. Included will be such matters as seasonal inspection lists and procedures, belt maintenance practices, fire system practices, boiler testing practices, safety inspections, insurance inspection practices, etc.

Here also will be discussed planning and scheduling of maintenance work as well as lubrication engineering and preuse spare parts testing.

#### Training of Maintenance Personnel

There is a need for planned systematic training of maintenance personnel, both salaried and hourly.

Practices at the Camas mill will be described and rationalized. Here will be covered such phases as induction and training of maintenance engineers and inspectors, night trade school courses, in-plant training courses for hourly employees, and the like.

#### Salvage Operations

Something that is badly lacking in many plants is an intelligent policy and practice with regard to parts that are removed from service. Unless planned otherwise, useless spare parts will take up too much valuable space and result in high handling costs. At the Camas mill a definite policy and practice has been set up and a salvage department created to make the policy and practice work. The salvage department operations will be described.

#### Conclusions

The effectiveness of maintenance can be increased and the cost decreased by proper maintenance organization, granting of proper status to maintenance, and by the establishment of standard practices, inspection, and training of maintenance personnel.

### Modern Bark Burning—Maynard H. Snodgrass, Detroit Stoker Co.

After considerable experimentation, it was decided that a spreader type stoker probably offered the best possibilities for burning both bark and coal fuel. The baffling of a standard B & W Stirling four-drum boiler was redesigned to secure the maximum flame travel before the combustion gases enter the boiler. This was equipped with a traveling continuous discharge type of grate that moves forward continuously and discharges the ash in a hopper beneath the operating floor line.

The bark is screened and that which passes through 2-inch openings goes to the bark bin from which it is distributed on the stoker. The coarse bark goes directly to the furnace by a gravity feed. The main bark and alternate coal fuel are fed from the same bin and fuel spouts but not usually simultaneously. It is possible to change from bark to coal without losing load or steam pressure.

A unit started April 1946 has operated satisfactorily in either bark or coal at more than the design capacity of 85,400 pounds per hour on bark and 100,000 pounds per hour on coal.

### Factors Involved in Selection of Stationary Steam Generating Units—W. S. Patterson, Combustion Engineering Co.

In discussing steam generating units it is first necessary to classify them as "small" or "large." The author has assumed that the dividing line is 100,000 pounds per hour steaming capacity.

The small units are generally those which will meet the requirements at the lowest cost. Many of the details such as construction, drum size, widths, tube lengths, are standardized but their selection will be influenced by such factors as existing space available, type of fuel burning equipment, type presently installed which allows interchange of parts, and draft conditions. In the small unit classification are horizontal return tubular (fire tube); three drum low head bent tube; box header, straight tube; two drum vertical bent tube; three drum vertical bent tube; four drum vertical bent tube; and sectional header straight tube.

The selection of a large steam generating unit demands consideration of certain basic requirements, all of which are involved. There are listed and discussed as: (1) customer's preference, (2) building limitations, (3) evaluations, (4) maximum capacity, (5) capacity range, (6) steam temperature, (7) steam temperature control range, (8) pressure, (9) fuel temperature, (10) fuel and analysis, (11) auxiliary

or future fuel, (12) nature of feedwater, and (13) desired efficiency.

In outlining the calculations involved in equipment selection, capacity, pressure, and steam temperature, determine the heat in the steam leaving the unit. The heat input in the fuel is determined and with the excess air sets the gas weight. The requirements of the superheater must be decided upon, and the furnace designed so as to give the desired leaving temperature. Influencing these decisions are such factors as the tube diameter and circuit length, gas flow, choice of construction materials, boiler surface, air preheaters, economizers, and pulverizers.

### Supercalender Roll Deflections and Crowns—J. B. Gough, Mead Corp.

The duty of a supercalender is, generally, to improve the surface finish on the paper it receives from the "all metal roll" calender on the paper machine, and to achieve various degrees of surface flatness, smoothness, gloss or reflectance, or combinations of these, to suit the customer's requirements, at as fast an operating speed as possible and with a minimum of breaks, splices, last time, and waste paper, and, at the same time, to accomplish this with a minimum loss of strength and opacity while retaining a reasonably high moisture content in the finished sheet. Further, the finish must be as uniform as possible across the entire width and in the length, be satisfactorily durable for the purpose intended, and with, usually, a limited increase in sheet density and reduction in caliper.

Additional requirements may be rapid ink absorption without spreading, smearing, or "strike-through," with a sufficiently soft elastic surface to take good clear type impressions without "skipping" and without fouling the type with loose fiber or mineral coating, if any.

It is the purpose of this paper to discuss only the effect of roll deflections and crowns on the above requirements and, more particularly, their effect on the uniformity of the surface finish across the entire sheet width, and on calender cuts, snap-offs, and broke; all of which are believed to be largely influenced by the roll deflections and crowns and their suitability for the particular number, diameter, face, and rigidity of all the metal and fiber rolls in the stock, as well as for the nip pressures in use and, to a minor degree, the "draw tension" in the sheet and the alternate methods of threading the sheet either directly into and out of the top and bottom nips, or over and under the top and bottom rolls.

### Hydraulic Mounting Technique for Roller Bearings—A. Stewart Murray, SKF Industries, Inc.

The SKF oil injection method for mounting and dismounting of large roller bearings is the by-product of solving another problem. The application of roller bearings to marine line shafting had been retarded by the lack of an effective and really practical rigid coupling. The engineering data and experience accumulated by developing a good rigid coupling were found to be of varied interest and applicable to interference fits as used in many heavy industrial applications.

Through the application of formulas for thick-walled cylinders as developed in Timoshenko's "Strength of Materials," Part II, it is possible to study the forces and stresses involved in a variety of conditions. Summaries of several SKF laboratory investigations on medium and large pieces show consistent and practical agreement with the theory. Also, this work studied both cylindrical and tapered bore bearings mounted on cylindrical and tapered journals respectively.

Bearing designs providing for the use of the oil injection system illustrate factually its advantages and convenience. Oil at pressures of 5,000 to 10,000 p.s.i. expand the inner rings of bearings and also develops the axial forces necessary to displace tapered bore inner rings up and down tapered journals. The paper industry's widespread use of interference mountings, involving bearings and journals with mating tapers, permits the fullest use of the potentialities of this system. Bearing applications recently mounted and currently being made for paper mills lend themselves to interesting theoretical analysis and study.

The SKF coupling depends on pressure only and unites two purely cylindrical shaft ends without the use of keys or any similar device. At the present time twenty-four couplings for 7⅜-inch shafting are being made for a specific order and this size is analyzed to show the stresses and strains that are employed to develop the high torque capacity. Oil pressures of 25,000 to 30,000 p.s.i. are used in mounting the couplings, and some additional consideration is required to handle these pressures compared to the lower ones employed in the mounting of bearings.

### Engineering Studies in Packings—H. G. Koch, Johns-Manville Research Corp.

The life of packings can be extended considerably, maintenance costs can be reduced, and production can be increased if the packings are carefully installed and intelligently adjusted during subsequent operation.

The behavior of packings and gaskets can be better understood by considering two basic principles which are involved in the control of leakage. These are (a) the packing must be so disposed as to constitute a continuous barrier to the passage of the fluid being handled, and (b) the packing must press against the mating equipment surfaces with a unit pressure somewhat higher than the pressure of the fluid being sealed.

It is important that the packing be installed in such a way that it provides this barrier to leakage, and that it be placed under sufficient unit pressure to satisfy the second condition.

During subsequent operation, the following factors tend to reduce the sealing pressure: (a) plastic flow of the packing material into voids within itself or in the equipment, (b) loss of material due to wear or abrasion, (c) thermal expansion effects, (d) attack or solution of the packing material by the fluids handled.

These factors are aggravated by heat generated by packing friction, and it is important that some leakage through the packing be tolerated if minimum operating temperatures and maximum life are to be obtained. The importance of leakage increases as shaft speeds and fluid pressures are increased. A convenient measure of the severity of a given application may be obtained by multiplying together the surface speed and the fluid pressure.

The recommended procedures for installing and adjusting packings and gaskets are presented in detail.

### The Electrofluid Drive—Fred W. Atz., Jr., Link Belt Co.

The electrofluid drive is a new and revolutionary drive engineered into a compact integral unit combining a standard general purpose motor with a fluid coupling. It is a highly efficient device, simple in principle and design. The fluid coupling consists of two main elements, impeller and runner, and power is transmitted entirely by the mass and velocity of moving oil between the two elements. The combined unit, motor and coupling, mounted in a cast iron housing, meeting N.E.M.A. motor dimensions, forms a packaged unit ready for operation.

There are many advantages inherent in this type of unit. The principle advantages are:

1. To eliminate shocks, impacts, and torsional vibration.
2. To insure continuous smooth operation.
3. To maintain full torque at all output speeds.
4. To permit the use of a motor closely rated to the developed load to be driven.
5. To prevent stalling of the motor.
6. To eliminate shear pins and other similar protective devices.
7. To permit the use of a standard motor (a.c. and d.c.) eliminating the use of high torque and high slip motors.

The application of this drive is widespread in industry in general. It has been successfully applied to slitters and cutters and, because of its characteristics it is adaptable to numerous other applications.

# Academic Aspects of Paper Stock Preparation*

By W. Boyd Campbell[1]

**Abstract**

*A theory of beating is presented which claims that the essential action for strength development is fibrillation; that this action does not create new surface but only exposes surfaces which already exist; that slow drainage is due to friction; that increased sheet density is due to increased capillary force; and that cellulose fibers unite because their surfaces are covered with layers of cellulose in partial solution which tends to crystallization on evaporation of the water.*

The value of a purely academic approach to the discussion of a subject is that it can be confined to the essential principles involved. Once these principles are clearly understood, the ways in which they can be applied are limited only by the ingenuity and imagination of the users of them.

The first principle of the making of paper lies in the fact that cellulose fibers, when wet with water and brought into contact with each other, become bonded to each other when the water is evaporated with the fibers still in contact. It follows that one essential of stock preparation is that this principle is used to best advantage and at least cost in labor, enargy and material.

The principle is not used to good advantage if the distribution of the fibers is such that an uneven sheet results. Hence the preparation of the stock must be done with this in mind. Prepared fibers must be in such a condition that they can be evenly distributed into a sheet. Since the fibers must adhere or bond to one another to a degree suited to the product being made and since the bonding is a matter of contact of cellulose surface with cellulose surface, the surface must be made available for such contact by the method of preparation. For reasons of efficiency these results must be effected at as low a cost as possible. That is, energy should not be wasted in doing the job either by doing more than is needful or by doing work which does not help the final result.

While the matter of preparing stock to give uniform dispersion comes last in point of time in the process it may be considered first.

In these days when chemical woodpulps play such a big part in papermaking, fiber dispersion does not play as large a part in stock preparation as it did when rag stock was the general raw material. Rag stock, regardless of any other treatment it may be given, must have the threads teased out to fibers and the fibers themselves reduced in length to allow of proper dispersion. Even in the case of chemical pulps with fibers of 3 or 4 mm. maximum length it is convenient, if not necessary, to cut them somewhat. With groundwood, it is necessary to remove all fiber bundles larger than some acceptable maximum. Those which are allowed to remain are seldom considered to help the quality.

## Screening

The operation of removing the unwanted fiber aggregates, whether strings or slivers, is generally effected by screening. And screening, when described in plain terms, is a pretty crude operation. A dilute suspension of stock is taken and an attempt is made to pass it through a lot of more or less fine holes. These holes may be narrow slots or they may be circular. In either case it is found that they quickly get blocked by fibers. So to remove the blockade the fluid suspension or the screen is given a quick move in the appropriate direction to remove the congestion and try again. Each time a few fibers pass the screen. Keeping up the process long enough finally gets through enough to use.

The holes in the screens are normally quite large in comparison with fiber dimensions. A complete wood fiber has a diameter of only 1/1000 thousandths of an inch or less. A fine-cut screen plate has slots of six to ten times this in width. A perforated plate screen has round holes of diameters from fifty to seventy times this fiber diameter. With the relative sizes of fibers and the holes in the screens, it is obvious that paper stock screens do not function as do screens for materials such as sand where the hole dimensions set a definite upper limit to the size of material which can pass. Instead, paper stock screens operate on a basis of probability. For any fiber dimension there is a definite probability of passing the screen on each attempt. Fiber bundles, coarse stiff fibers, and extra long fibers have a lower probability of passing than have finer and shorter ones. The probability is also influenced by some other factors. In dilute stock fibers are more free to turn and hence to follow the liquid stream lines and so the probability of passing is increased. It does not follow, however, that the relative probability of passing different kinds of fibers is altered. This may or may not be the case. The whole theory of screening is in need of study on a fundamental basis. There should be much room for improvement.

## Clotting

Assuming that the stock is satisfactorily screened and diffused, it should be kept that way until it reaches the machine wire. Unfortunately all stocks have a tendency to "clot" or "curdle" to some extent. Various pet theories have been advanced to account for this mostly based on experiences in connection with coagulation or precipitation of colloid suspensions. It is probable that there is some measure of truth in many of these theories in that they may account for a tendency of fibers to remain in contact once they touch. But such forces of attraction are small and only operate over extremely short distances. Eddy currents of very little energy break up such clots. If the fact is accepted that there is this ten-

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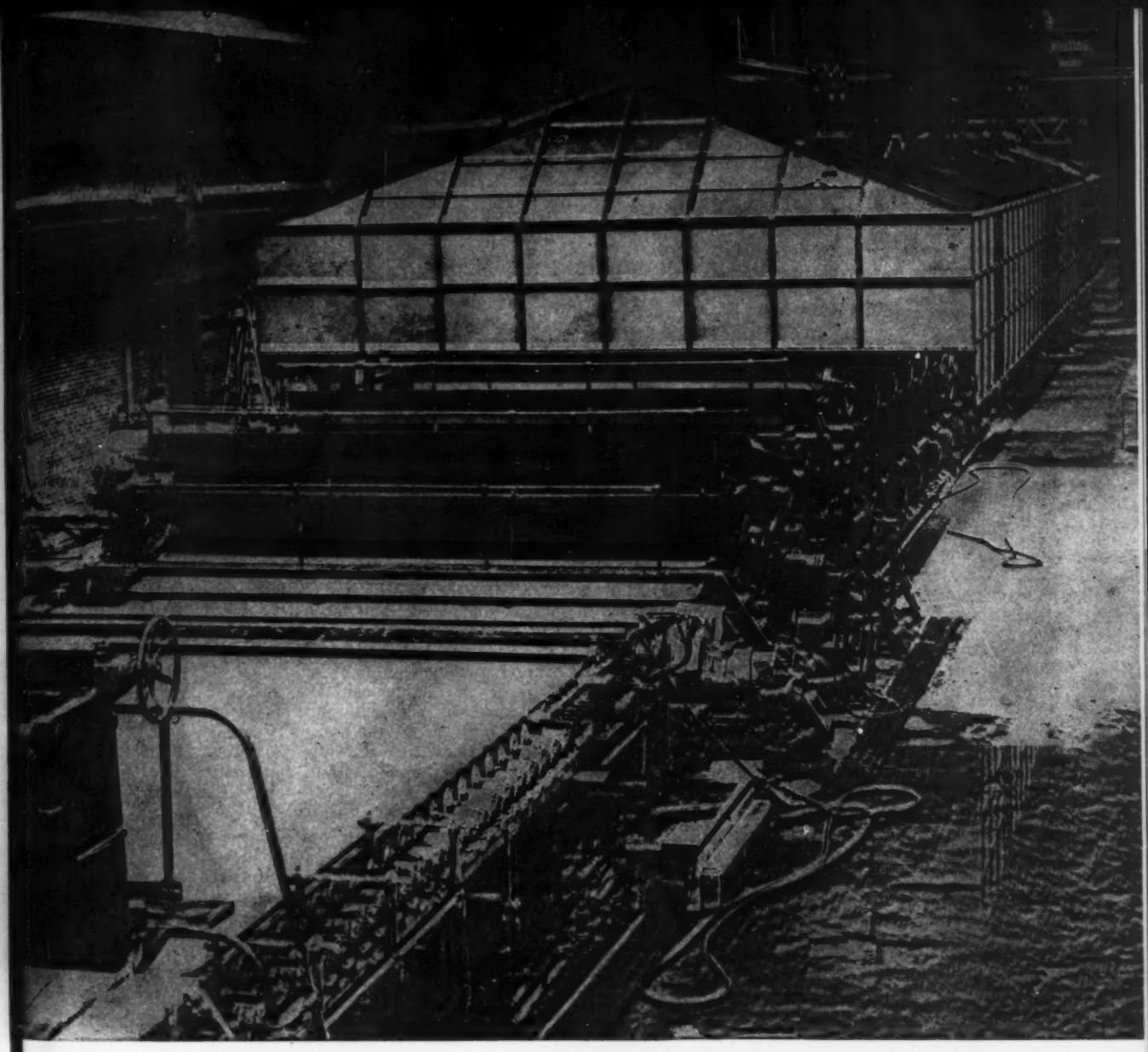

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dency to remain in contact a very simple explanation of clotting will cover the phenomena very well.

Clotting does not take place in stock which is completely without liquid motion. In a shallow dish, such as a large petri dish, a layer of stock will keep its formation until the water evaporates. Therefore the first postulate is that clots do not start or grow except as eddy currents of low velocity lead to fiber collisions. It is also known that eddy currents of moderately high velocity can break up clots already formed. So the affair may be pictured about as follows. Two fibers collide by chance action of currents. If the currents are of low enough velocity the fibers remain in contact. The probability of collision is proportional to some function of the fiber length and to some function of the concentration of the fibers. Hence long fibers clot more readily than short ones and high concentrations more readily than low for equal degrees of turbulence. Once two fibers contact they act as if they had become one fiber of greater length. Hence a third is more likely to be added and followed by a fourth and several more. But there are balancing factors. The mere gathering of several fibers in a clump or clot must denude the neighboring liquid of fibers and so diminish the probability of additions. Also the larger the clump grows, the greater is the probability of eddy currents of such a nature as to tear the clump apart to form two or more smaller ones. A balance is soon struck with the clots of sizes seldom far removed from a mean value. The picture may be followed out in more detail but the point of value at the moment is that clotting is basically a matter of eddy currents of low velocity. Whether clots formed in the flow-box persist through the slice or whether they are broken up but new ones form on the wire is a question which has not received a decisive answer. Yet it seems a point to be considered of fundamental importance if progress is to be made toward obtaining more nearly perfect formation.

### Stock Preparation

When the term "stock preparation" is used it generally refers, not to treatments leading to uniform dispersion, but rather to treatments which develop tensile strength or bursting strength, increase the sheet density and, usually, decrease the tear resistance. Such objectives are usually obtained by the action of the beater. Other equipment may be used with the same objectives. In the following the terms beater and beating action will be used to cover any apparatus and its action when used for this purpose regardless of whether the machine used is a disk refiner, a jordan, or even a grinder.

While the object of such preparation of stock is the development of strength in the finished sheet, the progress of the treatment is marked by the loss of freeness. This loss of freeness may be called by various names such as increase of wetness, increase of drainage time or drainage resistance, or increase of hydration. The latter term is, in the author's opinion, quite improper but it has become too generally used to be discarded at this late date.

Papermakers of an older generation, who knew no chemistry, did not speak of hydration. They distinguished stocks as wet or free and also as long or short so that a stock could be long and wet, long and free, short and wet, or short and free. These terms were both expressive and accurate. But chemists, in their ignorance, introduced the term hydration for increase in wetness, and it has stuck. The term hydration, in chemistry, implies that a substance has attracted to itself water and holds this water in a more or less strongly combined state. There are hydrated salts, for instance, where the water exists as water of crystallization such as $CaSO_4 \cdot 2H_2O$. There is also water of hydration which is attracted to ions in solution and moves with these ions. For instance, the hydrogen ion, commonly written as $H^+$, is almost certainly $H^+ \cdot H_2O$. Sugar molecules in solution also surround themselves with a number of water molecules which move about with them. It is possible and even probable, that cellulose in water has a layer of water molecules which are rather strongly attached to all available surfaces. To say that beating increases hydration means that beating increases the proportion of water so attached to the cellulose. And this simply does not take place.

The proof that beating does not alter the degree of any hydration that exists rests mainly on experiments where the vapor pressures of beaten pulps are measured. If two samples of pulp are taken and one of these is more highly hydrated than the other, then, at equal total water content of the two samples, that one where more water is bound to the pulp will necessarily show a lower vapor pressure. The attraction to the pulp must, to some degree, diminish the freedom to evaporate to produce vapor pressure. This must be true even if the additional binding is due to the creation of additional surface on which the extra binding can take place. But when the experiment is made with pulps at various stages of beating, even though the beating is carried to an extreme, it is found that the vapor pressure is unchanged. Hence it is quite definite that beating does not increase the degree of hydration of the pulp.

Now it is quite obvious to anyone who has handled beater stock, that water drains away from such stock much more slowly and reluctantly than it does from the same stock before beating. In the expressive term of the papermaker, the stock is "slow" or "wetter" and any theory of beating must account for this. Actually the explanation is not hard to find. Water drains from any mass of finely divided material more or less freely according to the size of the passages available for flow. If they are large flow is free; if small, flow is slow. In the beating the external surface of the pulp is greatly increased because of the breaking up into fibrils. And by fibrils is meant fiber-shaped portions of smaller size than the original fibers. These fibrils may or may not preexist in the original fibers. That is beside the point for the moment. The real point is that this increase of external solid surface, over which water must flow in drainage, greatly increases the frictional resistance to flow. Consequently drainage is more slow.

But it was mentioned a little earlier that hydration must be considered increased even if it only meant that there was created additional surface of contact of cellulose and water. Visible extra surface of cellulose has been created yet the vapor pressure experiments show that no additional water has been bound. This must be explained also and here the explanation is not quite so simple. Reference must be made to arrangement of cellulose molecules in the crystal and arrangement of cellulose crystals in fibers.

A molecule of cellulose is a long chain of similar chemical groups. Each of these groups may be called a $C_6$ group because of the six carbon atoms it contains. Joining of the $C_6$ groups is by means of oxygen atoms. Any one molecule of cellulose may be from 200 to 1500 groups long. In a natural cellulose these long chains tend to be grouped so that the $C_6$ groups

form a definite pattern in space. This pattern in three dimensions is the essential crystal structure. Because of the great length of the molecules, they can extend beyond any particular region of well defined crystal structure and may be part of several such regions. The crystalline regions, themselves variable in their dimensions but averaging about 50 molecules in cross-section, are therefore joined to each other by a variable number of long molecules which extend from a well-crystallized region through spaces where there are too few molecules to make a regular space pattern and on into crystalline regions again. The whole forms a fairly strong structure but one which has many regions of empty space.

In a fiber the general direction of the long molecular groups varies in different parts of the fiber structure. In a wood fiber the general direction of these in the interior is along the fiber length. Those on the surface tend to wind round and round the fiber. In cotton they are all spiralled. These arrangements are important because during beating fibers tend to break up so that the parts which shred off consist of fibrils or fiber portions in which the molecules are all of one general direction.

When water has access to the cellulose it fills in the spaces in the structure and, to some extent, it opens these up further. The enlargement comes about because the water penetrates between cellulose molecules wherever there are too few to make a good solid mass. Compared to the area of external fiber surface the area of contact between cellulose and water inside the fiber is enormous. A somewhat similar case is the area of a paper surface compared with the area of the fibers which make up the paper. In this circumstance lies the explanation of the fact that beating can greatly enlarge the visible and external surface of fibers without any appreciable effect on the total surface. It simply means that some surface, previously internal, has become external and therefore visible.

Qualitatively the increase of external surface provides an explanation of the increased slowness of beaten pulp. Whether the explanation is complete quantitatively will have to wait for better methods of measuring this surface and its effect on flow.

### Effect of Sheet Density

There now remains to be explained how such increased surface results in paper of greater density and of increased tensile strength. Consider first the increase in density. When the sheet of paper is ready for drying it consists of a mass of fibers and fibrils in more or less random arrangement. All the spaces in this mass, regardless of what material it is, provided it is not water repellent, will tend to contract because of the surface tension of the water. The same force which makes water rise in a capillary tube or a piece of blotting paper tends to pull the paper or the tube into the liquid,or, as in the case of the wet sheet, tends to make the volume contract. The force of the contraction is inversely proportional to the diameter of the capillary passage, or, more correctly, to the radius of curvature of the liquid surfaces. It is not essential that the liquid be in a tubular pasage; it may be only the liquid held in the nip between two fibers. An illustration of this is provided by a brush, wet with water, for instance a shaving brush. When only moderately wet the bristles pull themselves together. But when the brush is dipped in water, so that there are no more air to liquid surfaces, the tension is released and the bristles float apart. Likewise when the brush dries, so that again there are no air to liquid surfaces, the bristles come apart at the slightest touch. Provided that the fibers in a sheet are close enough when drying starts this surface tension force will pull them closer and make for greater density.

In the sheet of wet pulp, particularly if it has been pressed, the radii of the capillary passages is of the same order of size as the diameter of the fibers or fibrillae which make up the sheet. Hence, when the average fiber diameter is decreased by beating the size of the capillaries is also decreased and increase the pressure causing shrinkage. As for the cellulosic material itself there is not any appreciable difference because its shrinkage depends on the dimensions of the void space in the fiber and these are not effected by beating.

To illustrate the intensity of the pressures due to surface tension, it has been calculated that two round fibers of 0.003 cm. diameter lying parallel to each other and with a common water contact in the nip between them, will be pulled together with a force of nearly 90 pounds per square inch of contact. If these were smaller fibrils of diameter 0.0002 cm. the pressure would be 540 pounds per square inch.

Surface tension effects can account for the shrinkage which increases the density but some additional theory is required to account for the maintenance of this density after the water evaporates. Surface tension compresses the spring but there must be some kind of latch to hold it compressed. The following theory of the author is purely a speculation based on a series of known data but not experimentally tested otherwise. It accounts for the bonding on the basis of crystallizing forces.

### Cellulose Bonding

When a crystal of a soluble substance, sugar for instance, is placed in water the surface molecules of the sugar dissolve. That is to say, the attraction between themselves and water overcomes the attraction which previously held them in the crystal structure. If, however, a saturated solution of sugar is cooled slightly so that it holds a higher concentration than saturation calls for, then sugar molecules will leave the solution and will join with each other to form a crystal. When a sugar crystal is in contact with a saturated solution of sugar it neither dissolves or grows larger. But it is known that molecules on the surface of the crystal are continually changing places with molecules in solution. That is to say, the processes of both solution and crystallization go on but at equal rates so that the crystal suffers no change in size.

Now the molecules of cellulose consist of long chains of units which are essentially of the same chemical structure as the sugar glucose except that they are joined to each other. They should have the same attraction for water as sugar has and hence tend to dissolve. In this theory this tendency to dissolve is assumed. But since the molecule has a length of from 200 to 1500 of these sugar groups it is very unlikely that all of these in the chain should get into solution at one instant. At one or more points in the length, the thermal vibrations which helped them go into solution will be acting to put them back on the crystal. The effect is exactly as if the surface of the solid was covered by a saturated solution of cellulose but that the thickness of this saturated layer was limited to a fraction of the molecule length of the cellulose. Such a surface layer could well be called a layer of hydrated cellulose. According to this theory,

then, every surface of cellulose in contact with water is a surface of hydrated cellulose.

Once there are grounds for assuming such a hydrated surface it is not difficult to conceive of how it can function in cellulose bonding. Any two such surfaces which are close enough together so that the hydrated layers can mingle, will just naturally join together when water is evaporated from between them. The individual cellulose molecules, or parts of molecules, which have become surrounded with water are just as liable to join one face as the other. When all water is gone the two faces vanish into one continuous structure.

As to what characteristics of stock lead to easy beating or to greater bonding strength there is much speculation and little knowledge. From time to time observers have noticed that pulp is more easily beaten if the pentosan content is high. Other observers have noticed that a fair content of hemicellulose is beneficial. Still other data indicate that a small amount of residual lignin helps.

The many views have this in common, that a moderate amount of noncellulose makes pulp more easily beaten. This is quite readily understandable if the noncellulose is regarded as something interspersed in the cellulose structure in such a way as to introduce points or planes of weakness. Where these exist fibrillation, i.e., breaking into fiber-like shreds as a result of mechanical stressing in water, should be more easily brought about. The reverse argument, that a highly purified pulp should be difficult to beat, also holds. All beating treatments in practice tend, not only to fibrillate the pulp as is desirable, but also to cut the fibers, which is not conducive to strength development. Ease of fibrillation allows of better strength development since less cutting takes place.

To sum up, the theory of beating here presented claims that the essential action for strength development is fibrillation or the breaking down of fibers into fiber-like fragments of small diameter; that this action does not create new surface to any appreciable extent but only exposes surfaces which already exist in cellulose saturated with water; that the slow drainage of beaten pulp is due to the friction presented by the large external surface; that increased sheet density is due to the increased capillary force consequent on capillary passages of smaller cross-section; that all cellulose surfaces in water are covered with layer of cellulose in partial solution; that such surfaces, if brought into contact, unite by the crystallizing action of the cellulose on evaporation of water.

# Evaluation of Nine-Point Strawboard for Corrugating*

By Norval F. Wilson,[1]

**Abstract**

*A representative group of mills producing 9-point straw paper cooperated in submitting samples which were tested independently in the laboratories of Alton Box Board Company, Container Corporation of America, Institute of Paper Chemistry, and the Northern Regional Research Laboratory.*

*The test results were in close agreement and the product in each case was found to have certain desirable qualities necessary in the making of an acceptable grade of corrugated board. The Riehle compression test is clearly shown to be one of the most reliable indications of straw quality. Stiffness and tensile tests provide excellent confirmation. The amount of fiber other than straw in the furnish is reflected in the weight variations, which, in conjunction with caliper, showed that calendering had not produced as much difference in density as might be expected.*

An important source of fiber for papermaking is found in the agricultural residues. This report deals with the testing of 9-point corrugating medium made primarily from wheat straw. The TAPPI Committee on Testing Agricultural Residues was fortunate in obtaining samples from the regular production of a representative group of straw mills. Since the nine cooperating mills wished to keep the physical characteristics of their stock confidential, the samples were coded, and then distributed to four laboratories where independent tests were made. The laboratories deserving credit for conducting these tests are those of Alton Box Board Company, Container Corporation of

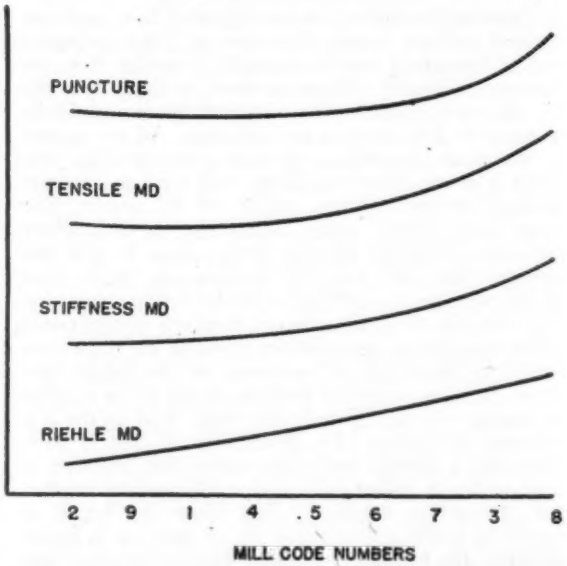


FIG. 1

* Presented at the Annual Meeting of the Technical Association of the Pulp and Paper Industry, Hotel Commodore, New York, N. Y., Feb. 24-27, 1947.

[1] Member TAPPI; Chairman TAPPI Committee on Testing Agricultural Residues; Chief Chemist, Alton Box Board Co., Alton, Ill.

TABLE I

Caliper (0.001 inch)

| Mill Code No. | a | b | c | d | Av. |
|---|---|---|---|---|---|
| 1 | 9.5 | 9.2 | 9.3 | 9.30 | 9.3 |
| 2 | 9.0 | 9.5 | 9.6 | 8.90 | 9.3 |
| 3 | 9.0 | 10.2 | 9.9 | 9.54 | 9.3 |
| 4 | 8.0 | 8.0 | 7.9 | 7.43 | 7.8 |
| 5 | 10.0 | 10.2 | 9.9 | 9.58 | 9.9 |
| 6 | 11.0 | 11.4 | 11.0 | 10.30 | 10.9 |
| 7 | 9.5 | 9.7 | 9.4 | 9.48 | 9.5 |
| 8 | 11.5 | 11.3 | 10.6 | 10.90 | 11.0 |
| 9 | 8.5 | 8.7 | 8.0 | 8.28 | 8.4 |
| | | | | Av. | 9.4 |

Weight per 1000 Square Feet

| | a | b | c | d | Av. |
|---|---|---|---|---|---|
| 1 | 33.0 | 33.5 | 34.2 | 33.0 | 33.4 |
| 2 | 32.0 | 30.0 | 31.1 | 32.6 | 31.4 |
| 3 | 33.0 | 32.7 | 32.4 | 32.1 | 32.6 |
| 4 | 29.0 | 29.5 | 28.2 | 29.5 | 29.1 |
| 5 | 32.0 | 32.0 | 31.4 | 31.4 | 31.7 |
| 6 | 32.0 | 31.9 | 31.1 | 29.9 | 31.2 |
| 7 | 32.0 | 31.4 | 31.6 | 31.3 | 31.6 |
| 8 | 34.0 | 34.7 | 32.3 | 32.4 | 33.4 |
| 9 | 31.0 | 30.4 | 29.8 | 28.2 | 29.9 |
| | | | | Av. | 31.6 |

TABLE II

Edgewise Compression (Riehle)

| Mill Code No. | MD a | MD b | MD c | MD Av. | OD a | OD b | OD c | OD Av. |
|---|---|---|---|---|---|---|---|---|
| 1 | 18.2 | 17.9 | 18.0 | 18.0 | 11.4 | 12.0 | 15.4 | 12.9 |
| 2 | 16.1 | 15.5 | 16.5 | 16.0 | 11.2 | 10.5 | 12.4 | 11.4 |
| 3 | 18.2 | 19.7 | 16.4 | 18.1 | 11.8 | 12.4 | 13.9 | 12.7 |
| 4 | 17.0 | 17.3 | 16.9 | 17.1 | 11.2 | 11.4 | 10.9 | 11.2 |
| 5 | 18.9 | 20.4 | 19.3 | 19.5 | 13.5 | 14.4 | 14.8 | 14.2 |
| 6 | 19.0 | 16.8 | 19.1 | 18.3 | 10.2 | 9.4 | 11.5 | 10.4 |
| 7 | 18.7 | 18.2 | 18.4 | 18.4 | 14.7 | 10.3 | 11.7 | 12.3 |
| 8 | 19.2 | 21.7 | 21.2 | 20.4 | 9.7 | 8.9 | 12.0 | 10.2 |
| 9 | 17.1 | 15.5 | 17.7 | 16.4 | 15.2 | 12.5 | 12.4 | 13.4 |
| | | | | Av. 18.0 | | | | Av. 12.1 |

| | Bursting Strength, pounds a | b | c | d | Av. | Beach Puncture b | c | Av. |
|---|---|---|---|---|---|---|---|---|
| 1 | 33.0 | 23.5 | 30.0 | 18.3 | 26.2 | 6.0 | 9.0 | 7.5 |
| 2 | 32.0 | 22.8 | 28.0 | 17.9 | 25.2 | 6.0 | 9.0 | 7.5 |
| 3 | 30.0 | 25.4 | 33.0 | 22.5 | 27.7 | 8.0 | 8.4 | 8.2 |
| 4 | 29.0 | 26.5 | 32.0 | 22.9 | 27.6 | 6.0 | 10.0 | 8.0 |
| 5 | 30.0 | 26.2 | 26.0 | 21.7 | 26.0 | 6.0 | 8.3 | 7.1 |
| 6 | 24.0 | 21.4 | 27.0 | 16.9 | 22.3 | 8.0 | 10.3 | 9.1 |
| 7 | 29.0 | 26.2 | 28.0 | 22.2 | 26.4 | 7.0 | 8.1 | 7.5 |
| 8 | 37.0 | 34.7 | 39.0 | 30.3 | 35.2 | 11.0 | 12.3 | 11.7 |
| 9 | 29.0 | 22.7 | 28.0 | 20.7 | 25.1 | 6.0 | 7.9 | 7.0 |
| | | | | Av. | 26.9 | | Av. | 8.2 |

TABLE III

Tensile—1-inch Width—Pounds

| Mill Code No. | MD a | MD b | MD c | MD Av. | OD a | OD b | OD c | OD Av. |
|---|---|---|---|---|---|---|---|---|
| 1 | 22.0 | 24.3 | 21.5 | 22.6 | 12.0 | 13.0 | 13.4 | 12.8 |
| 2 | 23.4 | 24.9 | 20.8 | 23.3 | 8.6 | 8.6 | 8.7 | 8.6 |
| 3 | 23.3 | 28.4 | 25.7 | 25.8 | 13.2 | 14.8 | 13.8 | 13.9 |
| 4 | 24.6 | 23.4 | 23.3 | 23.8 | 9.4 | 9.5 | 9.1 | 9.3 |
| 5 | 26.0 | 29.9 | 25.0 | 27.0 | 9.4 | 9.5 | 9.4 | 9.4 |
| 6 | 25.4 | 29.3 | 24.7 | 26.5 | 6.5 | 7.0 | 6.8 | 6.8 |
| 7 | 29.0 | 32.4 | 27.2 | 29.5 | 9.6 | 10.3 | 10.2 | 10.0 |
| 8 | 42.6 | 42.1 | 37.1 | 40.6 | 10.6 | 9.7 | 9.1 | 9.8 |
| 9 | 21.8 | 28.7 | 25.5 | 25.3 | 9.8 | 10.0 | 10.0 | 9.9 |
| | | | | Av. 26.0 | | | | Av. 10.1 |

Per Cent Elongation—1-inch Width

| | MD a | MD b | MD Av. | OD a | OD b | OD Av. |
|---|---|---|---|---|---|---|
| 1 | 0.5 | 0.9 | 0.7 | 1.8 | 1.8 | 1.8 |
| 2 | 0.7 | 1.0 | 0.9 | 0.8 | 0.9 | 0.9 |
| 3 | 0.7 | 1.0 | 0.9 | 1.8 | 2.2 | 2.0 |
| 4 | 1.0 | 0.3 | 0.7 | 1.3 | 0.6 | 1.0 |
| 5 | 0.8 | 0.9 | 0.9 | 1.0 | 0.6 | 0.8 |
| 6 | 0.8 | 1.2 | 1.0 | 0.6 | 0.9 | 0.8 |
| 7 | 1.0 | 1.1 | 1.1 | 2.0 | 1.7 | 1.9 |
| 8 | 0.8 | 1.1 | 1.0 | 1.8 | 2.0 | 1.9 |
| 9 | 0.7 | 1.1 | 0.9 | 1.3 | 1.0 | 1.2 |
| | | | Av. 0.9 | | | Av. 1.3 |

America, The Institute of Paper Chemistry, and the Northern Regional Research Laboratory.

Straw mills are usually equipped to make only a few essential tests such as caliper, weight, moisture, edgewise compression, and bursting strength. Not all mill laboratories have humidity rooms, and equipment for extensive tests. In this report, ample data are available for evaluation of the samples. Tabulation of the test results is based on the average from each of the four laboratories designated "a, b, c, and d."

## Summary of Data

Table I shows close agreement on caliper and weight. It is well to recognize that 9-point straw will not give very uniform tests even on samples taken from the same roll. Variations in the physical tests are natural and not necessarily due to differences in test equipment. Note that the over-all average caliper is 0.0094 inch, and that the average weight is 31.6 pounds per 1000 square feet.

Table II represents the edgewise compression test (Riehle) as reported by three laboratories. This is considered one of the most important tests made on 9-point straw. It gives some indication of what the crush strength should be on the finished corrugated board. In all the physical tests, actual strength is shown on the samples as made. Some would test better if the caliper and weight were up to normal.

Table III gives tensile and elongation based on 1-inch width samples. The importance of stretching quality in straw and its effect on the operation of a corrugator are often overlooked.

Table IV contains average test values which agree very well on stiffness and tearing strength.

Table V includes pososity, folding endurance, and per cent straw. The fiber other than straw is usually waste paper or selected kraft waste.

Figure 1 shows Riehle, stiffness, tensile, and Beach puncture values with the order of the nine mills rearranged as shown on the base line. Suitable scales were chosen for each curve. It is true that not all points fall on these curves, however, there are enough points to clearly define each curve.

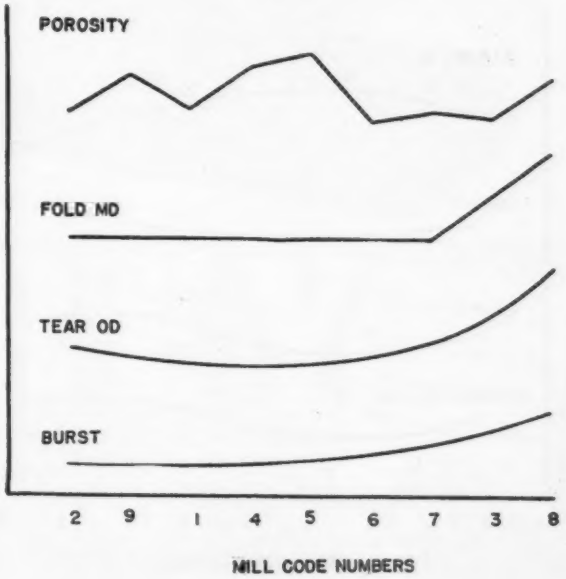


FIG. 2

It can be seen that the samples tend to increase in strength consistently for all the important tests.

Figure 2 shows the bursting strength, tear, fold, and porosity. The burst values are somewhat similar to puncture shown in Fig. 1. Tear and fold have little significance and porosity shows no relationship to other tests although the laboratory reports agreed fairly well.

Figure 3 is interesting because it shows the tendency for elongation to follow the caliper. Weight and caliper curves suggest that no particular improvement in the physical tests can be attributed to differences in density caused by unusual calendering. Where the percentage of fiber other than straw is high, the weight is correspondingly higher.

Figure 4 is a comparison of G. E. Beach puncture and bursting strength using one good grade of 9-point straw in a series of sandwich tests to determine whether more accuracy could be had with multiple plies. The results are close to straight line functions and it appears that sufficient accuracy can be obtained with a single sheet. This avoids an excessive number of samples and the extra work of alignment. Ordinarily puncture values on straw are small and do not show differences which would correlate with other tests.

A study of the various curves for physical tests together with the table of test averages will enable each mill to evaluate its product in relation to the others. This report covers the samples submitted, but does not necessarily indicate that regular production of any mill will continue to be the same. All of the samples have some desirable qualities, and all of them will make acceptable corrugated board. The objective is to improve the stiffness of 9-point straw produced at a standard weight and caliper. When this is accomplished while using a high percentage of straw in the furnish, it is certain that some progress has been made in handling the basic material. Numbers 3 and 7 are mostly straw fiber with normal caliper and weight, and the physical tests are very good. Numbers 4 and 9 are low in caliper and weight—otherwise might test better. Number 1 is an example of normal caliper with high weight. The Riehle was very good.

TABLE IV

Stiffness (Taber)

| Mill Code No. | MD b | MD c | MD Av. | OD b | OD c | OD Av. |
|---|---|---|---|---|---|---|
| 1 | 16.0 | 16.3 | 16.2 | 6.7 | 8.0 | 7.4 |
| 2 | 14.0 | 16.4 | 15.2 | 5.4 | 5.8 | 5.6 |
| 3 | 19.0 | 17.5 | 18.6 | 7.7 | 7.8 | 7.8 |
| 4 | 15.0 | 13.6 | 14.3 | 5.0 | 4.7 | 4.9 |
| 5 | 19.0 | 19.5 | 19.4 | 5.9 | 7.3 | 6.6 |
| 6 | 23.0 | 21.9 | 22.6 | 5.2 | 6.6 | 5.9 |
| 7 | 20.0 | 20.1 | 20.2 | 5.1 | 5.8 | 5.5 |
| 8 | 34.0 | 27.8 | 31.0 | 6.2 | 5.3 | 5.8 |
| 9 | 15.0 | 14.6 | 14.8 | 5.5 | 6.2 | 5.9 |
| | | Av. | 19.1 | | Av. | 6.2 |

Elmendorf Tear, grams

| | MD a | MD b | MD d | MD Av. | OD a | OD b | OD d | OD Av. |
|---|---|---|---|---|---|---|---|---|
| 1 | 64.0 | 64.0 | 59.8 | 62.6 | 80.0 | 75.0 | 69.1 | 74.7 |
| 2 | 64.0 | 56.0 | 67.5 | 62.5 | 80.0 | 92.0 | 75.5 | 82.5 |
| 3 | 80.0 | 77.0 | 74.9 | 77.3 | 80.0 | 89.0 | 77.8 | 82.3 |
| 4 | 48.0 | 56.0 | 48.0 | 50.7 | 64.0 | 73.0 | 62.1 | 66.4 |
| 5 | 48.0 | 54.0 | 55.4 | 52.5 | 64.0 | 75.0 | 67.2 | 68.7 |
| 6 | 64.0 | 85.0 | 72.3 | 73.8 | 112.0 | 129.0 | 101.0 | 114.0 |
| 7 | 64.0 | 66.0 | 64.0 | 64.7 | 80.0 | 87.0 | 78.7 | 81.9 |
| 8 | 96.0 | 103.0 | 113.0 | 104.1 | 160.0 | 158.0 | 149.0 | 155.7 |
| 9 | 64.0 | 65.0 | 61.8 | 63.6 | 80.0 | 80.6 | 69.4 | 76.5 |
| | | | Av. | 68.0 | | | Av. | 77.8 |

TABLE V

| Mill Code No. | Porosity, sec./100 cc. (Gurley) a | Porosity, sec./100 cc. (Gurley) b | Porosity, sec./100 cc. (Gurley) Av. | Per Cent Straw a | Per Cent Straw b | Per Cent Straw Av. |
|---|---|---|---|---|---|---|
| 1 | 17.5 | 23 | 20 | 96 | 95 | 96 |
| 2 | 16.3 | 22 | 19 | 93 | 80 | 87 |
| 3 | 19.3 | 17 | 18 | 96 | 95 | 96 |
| 4 | 33.9 | 38 | 36 | 97 | 90 | 94 |
| 5 | 37.7 | 50 | 44 | 95 | 80 | 88 |
| 6 | 15.3 | 15 | 15 | 88 | 80 | 84 |
| 7 | 20.1 | 15 | 18 | 96 | 90 | 93 |
| 8 | 37.5 | 31 | 34 | 76 | 95 | 66 |
| 9 | 39.1 | 31 | 34 | 94 | 85 | 90 |
| | | Av. | 27 | | Av. | 88 |

Folding Endurance—M.I.T.

| | MD a | MD b | MD Av. | OD a | OD b | OD Av. |
|---|---|---|---|---|---|---|
| 1 | 6 | 1 | 4 | 5 | 3 | 4 |
| 2 | 13 | 4 | 9 | 5 | 3 | 4 |
| 3 | 30 | 5 | 18 | 10 | 7 | 9 |
| 4 | 12 | 2 | 7 | 6 | 4 | 5 |
| 5 | 10 | 2 | 6 | 4 | 2 | 3 |
| 6 | 41 | 14 | 28 | 4 | 3 | 4 |
| 7 | 9 | 5 | 7 | 6 | 2 | 4 |
| 8 | 52 | 46 | 49 | 10 | 4 | 7 |
| 9 | 10 | 4 | 7 | 8 | 3 | 6 |
| | | Av. | 15 | | Av. | 5 |

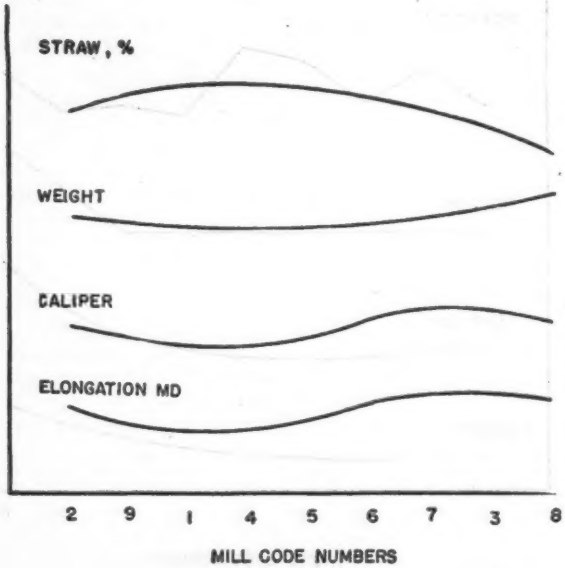


FIG. 3

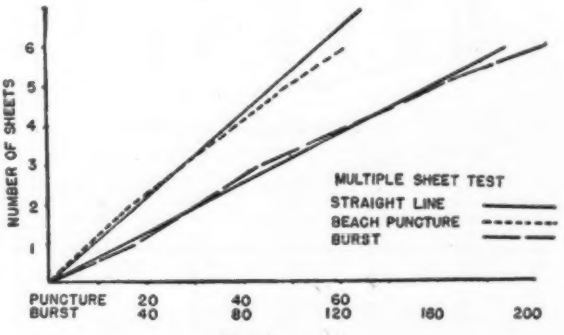


FIG. 4

NO SHOT IN THE DARK WITH

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Special consideration given to certain desirable combinations of tests will allow samples falling close together to exchange places in this evaluation. However it is believed that those samples on the low end of the curves could not from any point of view be considered better than those on the high end. It is hoped that this report will be helpful in studying the physical characteristics encountered in 9-point straw intended for corrugating, and that each mill can, with a knowledge of its own process and equipment, find some way wherein it is possible to improve its product.

# Pulping with Sodium Sulphite to Produce Strawboard*

By S. I. Aronovsky,[1] A. J. Ernst,[2] and H. M. Sutcliffe[3]


## Abstract

*A series of experimental laboratory cooks were made on sound, combine wheat straw. Lime and caustic soda, sodium sulphite, and various combinations of lime and sodium suphite were used as the pulping agents. The resultant pulps were evaluated for their strength properties and papermaking characteristics as described in a previously reported standardized procedure. The data obtained show that a mixture of 2% lime and 2% sodium sulphite, based on dry straw, produced an exceptionally free pulp which, when beaten and made into handsheets, had better strength characteristics and lower density than pulp similarly produced with the regular lime-caustic soda cooking agent.*


The use of sodium sulphite for pulping straw has aroused considerable interest recently in the manufacture of strawboard for corrugating paper. Sodium sulphite as a pulping agent is not new to the production of fine pulps and papers or even to the strawboard industry. It has been used in the commercial manufacture of specialty chemical wood pulps since about 1920. It is also the main pulping agent used in the production of semichemical pulps from wood *(1)*.

The pulping of straw and other agricultural fibers with sodium sulphite was patented by Cross *(2)* in England in 1880, and by Schacht *(3)* in Germany in 1900. Drewsen *(4)* obtained a U. S. patent on pulping agricultural residues in 1917, and a number of patents and articles in this field have been recorded in the literature since that time (5, 6, 7, 8). When sodium sulphite was used to replace lime in pulping straw for the manufacture of strawboard, the product had considerably less odor than the lime-cooked material (9), and somewhat better strength and operating properties.

In spite of these seeming advantages, however, sodium sulphite has not been used to any great extent in the commercial production of strawboard, mainly because of its relatively high cost. The market price of this chemical in the late 1920's was 6 to 7 cents a pound on the basis of the dry salt, a prohibitive figure. By manufacturing this chemical in the pulp mill proper from soda ash and sulphur, its cost could be brought down into a range roughly comparable with that of caustic soda. This procedure, however, is economically feasible only for relatively large-scale operation, as in the commercial production of wood pulps where large amounts of sodium sulphite are required for pulping. The chemical requirements of the average strawboard mill are relatively small and manufacture of the necessary sodium sulphite at the mill would not, therefore, be economical.

Recent work at the Northern Regional Research Laboratory has dealt with the correlation of the effects of various pulping processes for the production of fine specialty pulps from agricultural residues *(10)*. The results indicate that sodium sulphite pulping has a number of advantages over the other processes for delignification of these raw materials. This fact, coupled with the recent information that technical anhydrous sodium sulphite is available at reasonably low cost, as a byproduct of the chemical industry, led to the re-examination of the possibilities of this chemical for strawboard production. After this

* Presented at the Annual Meeting of the Technical Association of the Pulp & Paper Industry, Hotel Commodore, New York, N. Y., Feb. 24-27, 1947.

[1] Member TAPPI; Chemical Engineer in charge of Pulp and Paper Section, Agricultural Residues Division.[4]

[2] Paper Technologist, Pulp and Paper Section, Agricultural Residues Division.[4]

[3] Chemist, Pulp and Paper Section, Agricultural Residues Division.[4]

[4] Northern Regional Research Laboratory, Peoria, Illinois. One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

TABLE I.—YIELDS AND BEATING AND STRENGTH DATA ON PULPS PREPARED FROM WHEAT STRAW WITH SODIUM SULPHITE

[Liquor to solids ratio, 7:1, 5 hours at 140° C. (40 p.s.i.)]

| Cook No. | Chemical Used on Basis of Straw: CaO, % | $Na_2SO_3$, % | Other, % | pH of Spent Liquor | Yields on Basis of Straw: Washed Pulp, % | Fines, % | Test Data at Maximum Bursting Strength: Time of Beating, min. | Freeness (Schopper-Riegler), ml. | Bursting Strength, pts./ream lb. × 100 | Tear Resistance, g./ream lb. | Tensile Strength, g./ream lb. | Density, g./cc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| {509 {510 | 6.0 | ... | NaOH 1.5 | 8.7 | 74.6 | 5.5 | 45 | 385 | 65 | 53 | 122 | 0.70 |
| 506 | .. | 2.0 | ..... | 5.0 | 73.6 | 5.8 | 120 | 580 | 55 | 70 | 116 | 0.58 |
| 515 | .. | 2.0 | $Na_2CO_3$ 1.0 | 5.2 | 72.0 | 5.5 | 120 | 560 | 54 | 72 | 105 | 0.49 |
| 535 | .. | 2.0 | $Na_2CO_3$ 1.0 Sulphur 0.5 | 5.6 | 74.5 | 4.8 | 150 | 610 | 59 | 88 | 113 | 0.56 |
| 541 | .. | 2.0 | $Na_2CO_3$ 2.0 Sulphur 0.5 | 5.4 | 71.8 | 4.2 | 150 | 610 | 59 | 79 | 114 | 0.58 |
| 507 | .. | 4.0 | ..... | 5.3 | 72.8 | 5.1 | 120 | 630 | 64 | 87 | 137 | 0.62 |
| 508 | .. | 6.0 | ..... | 5.6 | 71.2 | 3.2 | 90 | 550 | 76 | 76 | 141 | 0.68 |

Strips of bece, or beech, wood served as "paper" for ancient Anglo-Saxons. From this was derived the Middle English term "boc," which, in our language, becomes "book."

# INTERESTING FACTS ABOUT PAPER

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work was begun it was learned that several strawboard mills had made commercial-scale trial runs on straw with the technical sulphite. While promising, the results of these trials were inconclusive, owing to the inability to determine with a fair degree of accuracy, under the conditions of these tests, such data as yield, ease of hydration, optimum strength properties, and so on.

Although the Northern Laboratory's data on sodium sulphite pulping for strawboard production are still incomplete, it is felt that the acute interest of the strawboard industry in this process warrants presentation of the preliminary results at this time.

The raw material was a bright, sound combine straw, relatively free from chaff, and from soft winter wheat grown in central Illinois in 1945. The methods of pulping and of pulp evaluation used in this work have been described in previous reports *(11, 12)*. The data on pulping, beating, and testing of the resultant pulps are given in Tables I to III.

## Discussion

The results of cooking the straw with sodium sulphite and other sodium salts are given in Table I. Data on a standard* lime-caustic cooked straw pulp are included for comparison. The pulp prepared with 2% sodium sulphite had higher freeness and tear resistance values than the lime-cooked pulp, but lower bursting and tensile strength and lower density. The addition of soda ash and sulphur seemed to have but little effect on these results. With increase in sodium sulphite from 2 to 6%, the yields of washed pulps, and total yields as well, decreased somewhat; the strength properties and density increased; and the freeness was apparently unaffected. The most noticeable characteristic of these sodium sulphite pulps is the high freeness at maximum bursting strength (in cooks 535 and 541 the beating was stopped at 150 minutes although the bursting strength values were still rising slowly), and the long beating periods required. These effects, in somewhat lesser degree, had also been observed in preparing fine chemical pulps from straw with sodium sulphite. The low bursting strengths of the sodium sulphite strawboard pulps are probably tied in closely with the relatively low pH values of the spent pulping liquors. Previous work on pulping straw with this chemical had shown that when the pH of the used liquor was substantially below 6, the resultant pulp fibers were brasher and more difficult to hydrate. This resulted in weaker fiber-to-fiber bonding and, consequently, in lower bursting and tensile strengths than are usually obtained with pulps produced under neutral or slightly alkaline conditions *(10)*.

After the above data were obtained, it was learned that, in the mill scale trials previously referred to, promising results were produced by cooking the straw with a mixture of lime and sodium sulphite. The optimum cooking mixture in these commercial runs, as indicated by observation of the washing characteristics of the pulp and its operating characteristics on the paper machine, consisted of 1.25% sodium sulphite, 4% lime and 1.25% sodium carbonate. Based on this information a number of laboratory cooks were made with this and other mixtures of these chemicals.

These data, found in Table II, show that the addition of lime to the sodium sulphite gave increased strength properties to the pulps, as compared with the straight sodium sulphite pulps and even with the regular lime-caustic pulp. At the same time, the hydration characteristics of the pulps were improved and the densities were still lower than that of the lime-caustic cooked pulp. It may also be noted that the pH values of the used liquors in this series did not go below 6.0. The pulp from cook 527, in which the same amounts and types of chemical were used, as reported for the optimum strawboard pulp in the mill-scale trials, was better than the lime-caustic straw pulp in all of the tests made. Use of the same formula, but without the soda ash (cook 531), gave a pulp with lower strength values but with higher freeness.

The best pulp in this series of cooks was obtained by using 2% lime and 2% sodium sulphite. The addition of 0.5% sulphur to this pulping formula gave a pulp with poorer hydration characteristics, lower bursting and tensile strengths and density, but better tear resistance; doubling the sulphur content decreased the tear value and increased the other strength properties.

The sodium sulphite and lime-sulphite pulps had, in general, a lighter color than the lime-caustic pulp. Probably the most interesting characteristics of the lime-sodium sulphite pulps are the relatively high freeness and lower density values at maximum bursting strength.

It would appear that these properties would make the lime-sulphite cooked pulps quite attractive; the faster draining pulp would result in a more porous, faster drying corrugating straw paper, which could thus be manufactured at a higher production rate. The lower density of the paper would result in pro-

* The use of 6.0% lime and 1.5% caustic was arrived at by averaging the actual chemical charges used in the commercial production of straw pulp in a large number of mills.

TABLE II.—YIELDS AND BEATING AND STRENGTH DATA ON PULP PREPARED FROM WHEAT STRAW WITH SODIUM SULPHITE AND LIME

[Liquor to solids ratio, 7:1, 5 hours at 140° C. (40 p.s.i.)]

| Cook No. | Chemical Used on Basis of Straw | | | pH of Spent Liquor | Yields on Basis of Straw | | Test Data at Maximum Bursting Strength | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CaO, % | $Na_2SO_3$, % | Other, % | | Washed Pulp, % | Fines, % | Time of Beating, min. | Freeness (Schopper-Riegler), ml. | Bursting Strength, pts./ream lb. × 100 | Tear Resistance, g./ream lb. | Tensile Strength, g./ream lb. | Density, g./cc. |
| 509 | 6.0 | .. | NaOH 1.5 | 8.7 | 74.6 | 5.5 | 45 | 385 | 65 | 53 | 122 | 0.70 |
| 510 | | | | | | | | | | | | |
| 531 | 4.0 | 1.25 | ..... | 7.1 | 74.3 | 5.7 | 45 | 535 | 63 | 62 | 115 | 0.60 |
| 527 | 4.0 | 1.25 | $Na_2CO_3$ 1.25 | 8.1 | 73.2 | 4.7 | 60 | 420 | 70 | 61 | 122 | 0.58 |
| 533 | 3.0 | 1.25 | $Na_2S$ 1.0 | 7.6 | 73.2 | 5.2 | 60 | 550 | 77 | 89 | 119 | 0.65 |
| 534 | 3.0 | 1.25 | Sulphur 1.0 | 7.0 | 74.6 | 4.4 | 45 | 570 | 73 | 71 | 135 | 0.64 |
| 518 | 3.0 | 1.5 | ..... | 6.4 | 76.4 | 4.5 | 60 | 490 | 62 | 66 | 117 | 0.50 |
| 532 | 3.0 | 1.5 | $Na_2CO_3$ 1.0 | 6.2 | 74.0 | 6.4 | 60 | 540 | 66 | 73 | 116 | 0.56 |
| 516 | 2.0 | 2.0 | ..... | 6.6 | 75.9 | 5.1 | 75 | 475 | 78 | 68 | 136 | 0.63 |
| 542 | | | | | | | 150 | | | | | |
| 536 | 2.0 | 2.0 | Sulphur 0.5 | 6.2 | 77.0 | 5.5 | 60 | 650 | 61 | 94 | 103 | 0.58 |
| *40 | 2.0 | 2.0 | Sulphur 1.0 | 6.0 | 73.8 | 5.2 | 90 | 550 | 72 | 81 | 132 | 0.70 |

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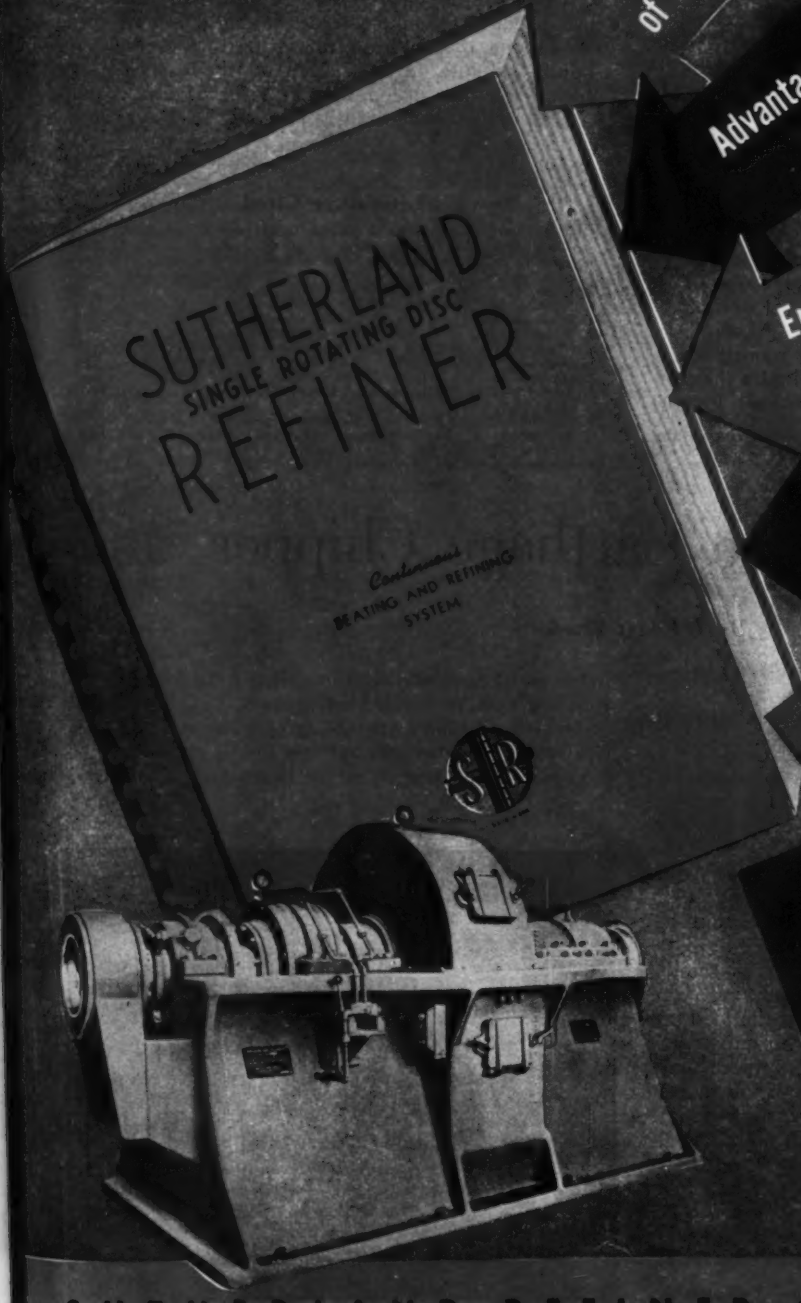


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TABLE III.—ESTIMATED COST DATA ON PULPING STRAW WITH LIME AND SODIUM SULPHITE [a] [b]

| Cook No. | CaO | | NaOH | | $Na_2SO_3$ | | $Na_2CO_3$ | | Total Cost per Ton of Pulp, $ |
|---|---|---|---|---|---|---|---|---|---|
| | Weight per Ton of Pulp, lb. | Cost, $ | Weight per Ton of Pulp, lb. | Cost, $ | Weight per Ton of Pulp, lb. | Cost, $ | Weight per Ton of Pulp, lb. | Cost, $ | |
| {509 {510 | 165 | 0.83 | 41 | 1.02 | .. | ... | .. | ... | 1.85 |
| 527 | 110 | 0.55 | .. | ... | 34 | 0.68 | 34 | 0.43 | 1.66 |
| {516 {542 | 55 | 0.28 | .. | ... | 55 | 1.10 | .. | ... | 1.65 |

[a] Based on CaO at $10 per ton, NaOH at $50 per ton, $Na_2SO_3$ at $40 per ton, and $Na_2CO_3$ at $25 per ton.
[b] Based on a yield of 73% pulp from straw.

ducing more paper per unit of pulp. This could be accomplished, in accordance with the above data, without sacrifice in yield of pulp and with an appreciable gain in strength characteristics. It must be noted, however, that more beating, and therefore more power, is required to hydrate the lime-sodium sulphite pulps to obtain their maximum bursting strengths. The increased freeness and lower hydration rate of this type of strawboard pulp were also noted in the commercial-scale trials.

The consumption of chemicals and their estimated cost per ton of pulp, for three types of cooks (509-510; 527; 516 and 542), are shown in Table III.

These data are based on a yield of 73%* pulp from the straw (straw and pulp both on moisture-free basis). It is seen from Table III that, under the conditions reported here, the cost of chemicals for the lime-sulphite pulps is less than that for the lime-caustic pulp. It must be emphasized that these cost estimates are based on only a few experimental cooks, and they cannot be applied to mill operation except where identical types and amounts of chemical, and sound, relatively chaff-free straw are used.

Eighteen experimental laboratory cooks were made on sound, combine wheat straw with lime and caustic soda, sodium sulphite, and various combinations of lime and sodium sulphite. The resultant pulps were evaluated for their strength properties and papermaking characteristics in accordance with a standard procedure developed at the Northern Regional Research Laboratory.

Although the data reported here are considered insufficient for the purpose of making definite recommendations, they indicate that a mixture of lime and sodium sulphite (2% of each on the basis of dry straw) will produce a normal yield of straw pulp with favorable strength properties and operating characteristics.

* *Note:* It is believed that the generally assumed commercial yield of 67% pulp, based on straw, is too low if the straw is both sound and relatively dry.

### Literature Cited


1. Rue, J. D., Rawling, F. G., Wells, S. D., and Staidl, J. A., *Paper Trade J.* 83, No. 13: 50 (Sept. 23, 1946); also West, C. J., Bibliography of Paper Making, 1900 to date, for numerous articles in semichemical pulping.
2. Cross, C. F., Brit. pat. 4,984 (1880).
3. Schacht, W., Ger. pat. 122,171 (1900).
4. Drewsen, V., U. S. pat. 1,229,422 (June 12, 1917).
5. Braun, C. A., U. S. pat. 1,387,441 (Aug. 9, 1921).
6. Clark, J. d'A., *World's Paper Trade Rev.* 85: 1522 (1926).
7. Drewsen, V., *Paper Trade J.* 83, No. 24: 41 (Dec. 9, 1926).
8. Hausen, J., *ibid.*, 84, No. 9: 51 (March 3, 1927).
9. Rue, J. D., and Monsson, W. H., *ibid.*, 81, No. 15: 52 (October 8, 1925).
10. Unpublished data, Northern Regional Research Laboratory.
11. Aronovsky, S. I., Younger, J. O., and Nelson, G. H., *Paper Trade J.* 120, No. 8: 124 (February 22, 1945).
12. Younger, J. O., and Aronovsky, S. I., *ibid.*, 120, No. 19: 43 (1945).


# Drive for the Carthage Chipper*


By J. Edgar Rhodes[1]



### Abstract

*A short description is given of the drive installed on a ten-knife Carthage chipper.*


The Carthage chipper has enormous capacity for chipping wood, and reports indicate that it gives high yield with low loss and produces chips of the proper dimensions at a favorable cost.

The solid cast grey iron alloy disk 7 feet or more in diameter and weighing over 5 tons is safe and insureable for rim speeds up to 7200 feet per minute. This, along with a heavy driven pulley weighing 2 or 3 tons on the same shaft will store an enormous amount of energy. They help greatly in keeping up the cutting speed and tend to smooth out the load on motor and belt when the largest logs are cut. It is reported that in one test 66½ cords of southern pine were cut in 1 hour on a 96-inch chipper running 360 r.p.m., using 247.7 horsepower hours. This low figure of 3¾ horsepower per cord is not considered practical under ordinary conditions, and it is understood that the manufacturer recommends 6 horsepower on similar wood and 8 to 10 horsepower on hardwood.

Limiting factors in many mills will not permit operating this type of chipper continuously at full capacity, but even when operated at less than full capacity, it is reported to have decided advantages.

To return to the matter of driving the machine, it is clear that with the great inertia in the rotor and the high peak loads at the time of heavy cuts, a nonrigid

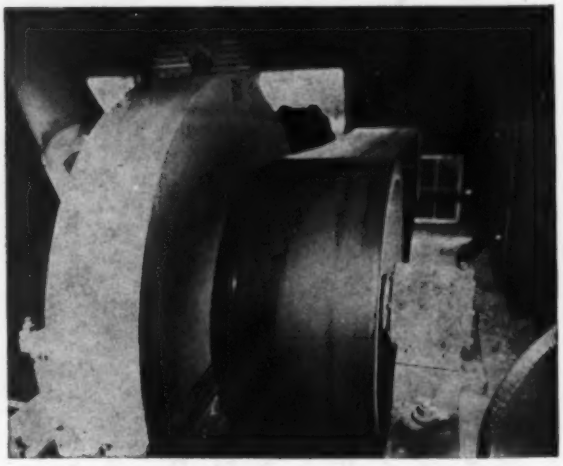

FIG. 1

* Presented at the Annual Meeting of the Technical Association of the Pulp & Paper Industry, Hotel Commodore, New York, N. Y., Feb. 24-27, 1947.

[1] J. E. Rhoads & Sons, Philadelphia, Pa.

type of drive is indicated. The chipper shaft runs at roughly half the speed of the motor. For economy, a fairly high speed motor is desirable and one should be chosen of a type suitable for the nature of the load, bearing in mind starting, normal, and peak loads, and their duration.

Experience on many types of heavy machinery with shock loads or with heavy starting torques has shown that one of the most dependable and efficient types of drive consists of a suitable motor mounted on a properly designed pivoted base which will insure maintenance of proper belt tension at all loads, and with pulleys and bet of suitable type. It is possibe to design the whole unit so as to give thoroughly dependable performance along with extremely low maintentance. Thousands of these pivoted motor base drives of all sizes up to 500 hp. or more have proven their reliability and great efficiency. Flat pulleys with a specially tanned leather belt of appropriate type and size will give excelent resuts. Properly designed and installed, this drive automatically maintains correct belt tension under varying loads. More machine production is nearly always obtained. Some very heavy and difficult drives in other industries have proven the reliability of the pivoted motor base drive in comparison with various other types.

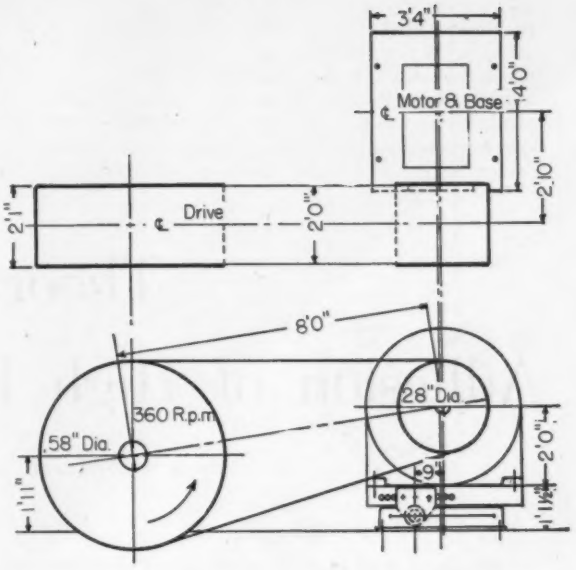


FIG. 3

**84-inch Ten-Knife Carthage Chipper Drive. 200 h.p., 730r.p.m. Motor. 16-B Rockwood Base. 24-inch Heavy Three-Ply Special Tanned Belt.**

### Torque Starter

One such drive on a 84-inch ten-knife chipper which was started up early in November 1945 has operated 12 hours per day, 6 days per week and is still running satisfactorily without any failure. It is cutting poplar wood averaging around 8 inches with a maximum diameter of about 15 inches. Its output is limited by the chip handling system. The user reports there is definitely no slowing up of the chipper speed when either large or small wood is fed into it at the rate their system can handle the chips. A 200 hp., 750 r.p.m. wound rotor motor is used. This happened to be a motor already available. However, it does make possible starting up satisfactorily in a period of 3 or 4 minutes. It is fairly certain that a more economical set-up would be a standard induction motor with a Bethlehem slip ring torque starter in the motor pulley. This combination has been used for years in a number of types of machines with load characteristics similar to those of a chipper. It will prove more economical in first cost than a wound rotor motor. This set up should work well with the ordinary intermittent rate of feed of logs that are not too large. However, where nearly continuous feeding of heavy logs or hard wood requires the maximum capacity of the chipper it might prove safer to use a wound rotor motor with a suitable block of external resistance in the circuit.

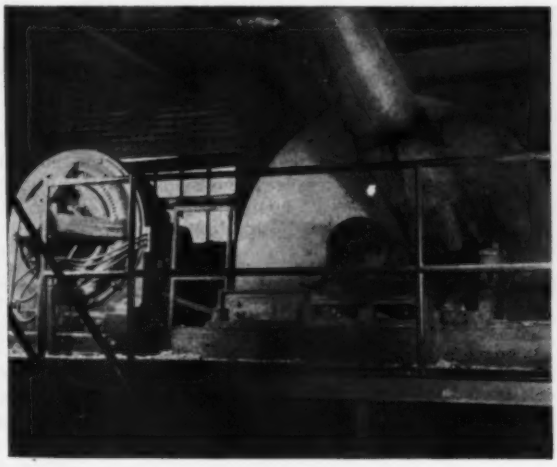

FIG. 2

Other advantages of using such a torque starter are that it picks up the load very gradually, that it acts as an excellent protection in case of jamming, and will safeguard machine, motor, and belt. In addition, experience has shown that it is possible to design a torque starter of this type so that any load more than 2% in excess of the predetermined maximum will result in slippage and no serious damage can result.

Such a starter also makes possible the use of a motor adapted to the running load characteristics of the machine rather than the starting load.

In some types of machines the connecting belt serves as a safety valve and if jamming occurs, it will slip and protect the machine and motor. It is usually damaged in the process. With small machines, this is often the safest thing to do where protection is required. However, where a considerable amount of power is involved, and especially where the machine is subjected to very high peak loads at frequent intervals, the use of a belt to slip will not prove advantageous. If subjected to appreciable slip over a matter of months excessive deterioration occurs. Production will also almost certainly be lost as any belt which will slip when severely overloaded is not likely to pick up the load again and bring the driven machine to full speed as quickly as a belt with high coefficient of friction kept at the proper tension. When a belt is run at low tension, it will not transmit anything like full load unless it has abnormally high coefficient of friction.

Either there will be too much slippage and lower production, or the belt may fail to slip at the time when jamming occurs before damage results.

Experience in many fields, has indicated that better production, more economy and efficiency, and also lower maintenance will be realized if machines are driven as recommended above with a motor suitable as to size and type, mounted on a pivoted base to maintain the belt tension, using a special tanned leather belt with high strength and high coefficient of friction and, a torque starter in the motor pulley.

One large corporation has used over a thousand of these units on machines requiring 500 hp. and down almost entirely as a protection for expensive

# Theory of the Adhesion of High Polymers to Cellulose*

By A. D. McLaren[1] and C. H. Hofrichter, Jr.[2]

**Abstract**

*The adhesion of high polymers to cellulose involves a number of physical perameters including the dielectric constant of the polymer, the dipole moment of polymer constituents, the facilities for hydrogen bonding at the polymer cellulose interface and the micro-Brownian movement of chain segments. Here the influence of polar group concentration and polymer viscosity only, have been considered.*

*The concentration of carboxyl groups (maleic anhydride residues), was varied in a polymer composition of vinyl chloride-vinyl acetate copolymer admixed with vinyl chloride-vinyl acetate-maleic anhydride interpolymer. Such compositions were coated on regenerated cellulose.*

*Experiments showed that adhesion to regenerated cellulose, which was assumed to be a measure of the COOH⟶OH dipole-dipole bonds formed, increases in a manner expressible by: Adhesion = k (COOH)$^n$ reminiscent of the Freundlich sorption isotherm. At any given carboxyl concentration adhesion increases with temperature. This may be interpreted as indicating that the development of an adhesive bond involves an exothermic heat of sorption as well as the highly endothermic activation energy for viscous flow. The latter energy is a measure of the process of the chain segment motion which is necessary to permit more dipoles within the polymer to approach the vicinity of the active centers in the substrate. Application of the Guzman equation relating the viscosity to the activation energy for viscous flow to the rheological measurements on the polymer composition shows this energy to be of the order of +30,000 calories (endothermic). Application of the Clausius-Clapeyron equation to the measurements of adhesion gives the heat of adhesion involved in the combined processes to be +12,500 calories. By difference, one may obtain the heat of sorption for maleic anhydride residues groups on cellulose to be approximately —17,500 calories (exothermic).*

In general, there are two types of adhesion, specific adhesion and nonspecific adhesion. The former, exemplified by the cohesion of two polished surfaces of optically planar metals or glass in the absence of external adhesive, is irrelevant to our present concern. Nonspecific adhesion involves the presence of an adhesive, and may be broken down into microscopic and submicroscopic factors. The gradation is, of course, gradual and no doubt arbitrary.

MICROSCOPIC FACTORS MAY INVOLVE:

1. Porous surfaces. Binding of porous surfaces involves the purely mechanical embedding of the adhesive in the pores. This kind of joint may be sharply contrasted with those joints between polished surfaces, which depend upon interaction of surface and adhesive via secondary valence forces.

2. Rough surfaces. With rough surfaces improved adhesion is probably due primarily to the increased microscopic surface area per gross unit area.

3. Thickness of the coating. Generally for metals the thinner the adhesive film the better the adhesion *(1)*. This increase in adhesion with increasing thinness of coating may in part be due to a molecule-molecule chain effect exhibited by a thin film of the adhesive; the chains tend to bond together the surfaces involved with greater force than can exist with a more random molecular orientation present in a thick film.

With cellophane, on the other hand, generally the thicker the coating the greater the adhesion as measured by peel heat-seal strength. This is probably because stress is spread over greater volume in thicker coatings.

SUBMICROSCOPIC FACTORS MAY INVOLVE:

1. Size and similarity of crystal unit cells, or in the case of amorphous substances, the particle size. Of importance here also is the past history of the surface and the presence of impurities. Impurities such as a softener or plasticizer may be good or bad as regards the promotion of adhesion. Frequently a fractured nascent surface has "hot spots" or points of unsatiated electric fields. The absorption of gases at the spots destroys the potentialities for optimum adhesion. Crystal-crystal orientation is sometimes important. Generally speaking, crystals are not isometric and as an accompaniment the adhesive forces involved are not the same in all planar directions. As is generally known, in most crystalline or liquid crystalline materials, a periodicity (100 to 10,000 A°) of density occurs which may lead to crack formation. Such cracks, which may often be ironed out by heat and

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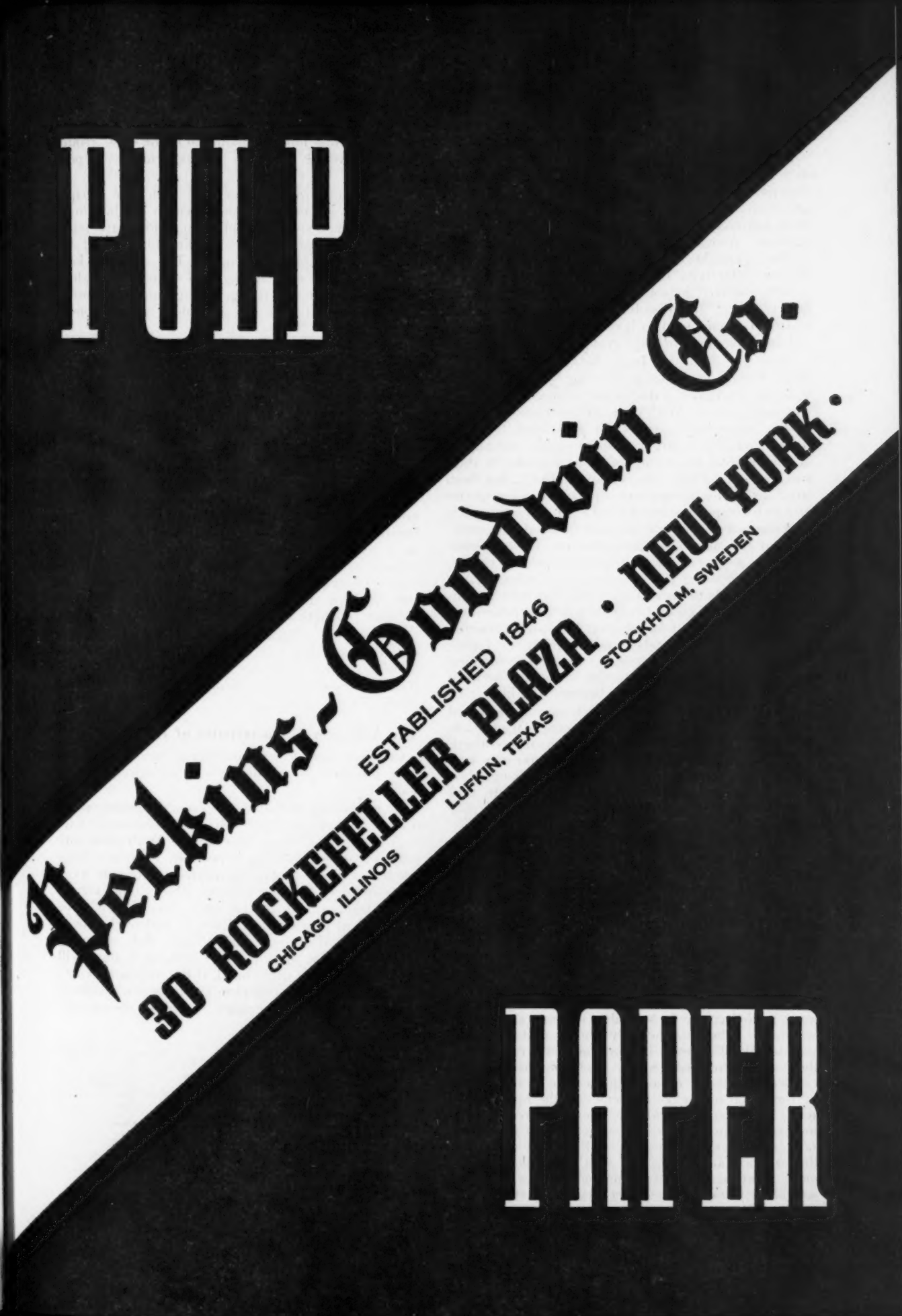
* Presented at the Annual Meeting of the Technical Association of the Pulp & Paper Industry, Hotel Commodore, New York, N. Y., Feb. 24-27, 1947.

[1] Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
[2] E. I. du Pont de Nemours and Company, Inc., Buffalo, N. Y.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quenching treatments, are potentially weak spots which open up with the application of stress at a low rate *(1)*.

2. Molecular architecture. McBain *(1)* has shown that strong joints may be obtained with any liquid material which can wet both surfaces to be joined and then solidify *in situ*. The adhesive strength of such substances varies in relation to chemical constitution. Aromatics give stronger joints than aliphatics. Straight chain unbranched compounds are all poor adhesives. It is not unlikely that the same factors involved in solubility *(2)* will apply to adhesives, (i.e.: "like dissolves like"). Substances with hydroxyl groups tend to bond well with other materials also having hydroxyl groups.

Since the time of Isaac Newton, it has been realized that the attraction existing between any two material aggregates is due to the residual electrostatic forces at surfaces. With molecules, attraction depends on the "secondary valences" or unsatiated "fields of force" and, "with larger groups, on the summation of the residual electronic forces in subunits in their surfaces"*(1)*. That "like dissolves like," has been attributed to the presence or absence of polar species in a two-component solution *(2)*. In a solution of a nonpolar substance with a polar material, the molecules of the latter show an attraction for each other and exert a squeezing out effect on the nonpolar molecules, thus leading to a diminution in solubility. In the case that both species are polar but have magnitudes of polarity quite divergent, a similar effect may be apparent but to a lesser degree. Increased attraction between unlike molecular species leads to higher solubility and may eventually lead to compound formation in the case that the attraction between unlike molecules exceeds that between the like.

In reality matters are even much more complicated and resist any quantitative statements. Dipoles are not additive and depend upon the structure assumed. As Mark has pointed out, dipole attraction may lead to hydrogen bonding and hydrogen interchange *(3)*, as in the case of alcohols, hydrogen fluoride, and water. Thus, through resonance enhanced union may take place.

On the other hand, dipoles which would mutually attract each other may be covered up by aliphatic chains to the extent that the dipoles never achieve the juxtaposition necessary for bonding *(3)*. Thus, according to Hildebrand, the degree of aliphaticity, that is, the extent of presence of aliphatic groups of homopolar character, may eventually lead to structures closely corresponding to hydrocarbons *(2)*, to the complete submergence of the dipole attached (mutual interaction falls off almost inversely as the cube of the inter dipole distance *(3)*). In solution this leads to a decrease in solubility of, say, alcohols in water. In adhesion, the only forces remaining are van der Waal's forces between aliphatic chains and these are notoriously weak. Such an effect of increased aliphaticity is noted in the case of the energy of formation of double molecules in the homologous series of carboxylic acid; the energy decreases with increased chain length *(3)*. On the basis of the aforesaid and the experimental work, it may be concluded that solution and adhesion are in part, and in common, manifestations of a common factor, that of secondary valence forces. The degree of aliphaticity and/or the possibility of resonance and hydrogen bonding serve to complicate the picture in most instances. This outlook is not new; McBain found that in cementing together various metals, most substances yielding strong joints contained -OH or -CO- groups. Strong bonding can only be expected with polar groups.

3. Physicals of the interfacial film. The strength of a joint depends upon the strength of the film at the interface: stresses applied to a joint are transmitted to the surfaces. The binding film should also be elastic, flexible, and ductile. The adhesive layer must be capable of adapting itself to changes in shape and volume due to wetting, drying, and to deformations co-existent with, and dependent on atmospheric conditions.

Materials possessing the most powerful adhesive action are those which are near, but not quite in, the zone of true or crystalloidal solution or degree of dispersion in solvents or in space: the zone of maximum colloidal character lies between aggregate and solution particle sizes. Colloid to colloid adhesion is usually better than colloid to crystalloid.

4. Charge. It is anticipated that two substances will tend to adhere if they inherently bear opposite charges when dispersed. When a substance partially decomposes as it is laid down on the surface, many new bonds are formed. This bond formation will result in a grabbing at the nearest susceptible residual valence whether it be in the substrata or in the substance decomposing. Such a principle is often observed in the character of adhesion between decomposition products and the floor of a reaction vessel.

5. Tackiness. Tacky substances show adhesive action because of easily movable segments of the chains of macro-molecules and by the intermolecular forces of these segments, according to Josefowitz and Mark *(4)*.

### The Adhesion Characteristics of High Polymers

Common knowledge concerning the adhesion of high polymers to cellulose is summarized *(5)* in Table I.

By examining this table, and from statements made below, it may be concluded that substances with hydroxyl groups adhere to cellulose. With such substances hydrogen bonding is possible. There is a large number of dipole-containing polymers with only weak or no hydrogen bonding facilities which do not adhere well. Quantitative data on such materials will be published at a later date. Even if hydroxyl groups are present, if the substances have high softening points (cellulose acetate, ethyl cellulose) they will not adhere. On the other hand, if the softening points are quite low (polyisobutylene) polymers will adhere in the absence of polar groups. As will be shown else-

TABLE I.

| Polymer | Adhesion to Cellulose |
|---|---|
| 66 Nylon | Poor |
| Polyvinyl alcohol | Excellent |
| Urea or Melamine-formaldehyde resins | Excellent |
| Butacite | Poor |
| Rubber | Poor |
| Rubber hydrochloride | Poor |
| Polyisobutylene | Good |
| Polyethylene | Poor |
| Cellulose acetate | Poor |
| Ethyl cellulose | Poor |
| Cellulose nitrate | Good |
| Polyvinyl chloride | Poor |
| Saran | Poor |
| Polyvinyl acetate | Poor |
| Polystyrene | Poor |
| Copolymers of vinylhalides | Poor |
| Copolymers of acrylonitriles | Poor |
| Copolymers of acrylic esters | Poor |

where *(6)*, there exists a balance among the factors of polarity, aliphaticity, and softening point.

The adhesion values of various polar groups in polymers to cellulose are probably in the same order as the affinity of these groups for water. We have the latter data from water vapor sorption by high polymer experiments, and reported elsewhere *(7)*. The order of increasing adhesion to cellophane for the following would be alkyl, nitrile, chloromethylene, dichloromethylene, butyral, and hydroxyl. This seems to roughly follow the order of adhesions found for these groups.

Two qualitative factors involved in the adhesion of high polymers to cellophane may be combined to give a semistatistical picture of their influence.

Mark and Josefowitz *(4)* have pointed out that a certain degree of molecular mobility is required to produce stickiness. For adhesion the material must not be too fluid, however, and thus lack body and resistance to stress. In other words, the material to be a good adhesive must have the proper viscosity range (100 to 10,000 poises). Tack temperature (a semiquantitative measure of melt viscosity) runs parallel to viscosity (see below) and hence is a qualitative measure of same. The ability for a material (1) to merge or flow fairly rapidly at or slightly above room temperature and (2) to resist forces of stress and shear if an attempt is made to separate the polymer from an interface is a function of a fairly wide temperature range (25 to 90°). The addition of a plasticizer or a slight increase in temperature can markedly change these properties of a substance *(4)*. The influence of molecular weight is discussed below.

Once a polymer is laid down at an interface under optimum viscosity conditions (from a solvent) it must remain adapted to the interface. This can only be true if the materials possess a viscosity (tack temperature) below what may be an upper limit for a given substrate. The transition from a condition of solution to a condition of solvent free plastic is probably analogous to the transition between a second order viscous liquid-elastic solid transition. Such a transition is known to result in relatively great dimensional changes (8). It tends to reduce adhesion. A further setting of the material on reduction of temperature must result in a further tendency to shift at the cellulose interface. Only by possessing a sufficiently low viscosity can the material preserve its dipole bonding to the cellulosic hydroxyl groups. For example, when first coated on cellulose, polyvinylidene chloride-isobutylene adheres very well; during the new half hour it crystallizes and as it does so, the adhesion falls to a very low value.

Flory *(9)* has shown that the melt viscosity, $\eta$, of related polymers may be expressed by a relation of the type

$$\log \eta = A + CM^{1/2} + B/T \qquad (1)$$

where $A$, $B$ and $C$ are characteristic of the polymer series (polyesters for example) and $M$ is the weight average molecule weight. *Tack Temperature* may be defined as that temperature at which the melt viscosity becomes low enough for two slabs of polymer to merge at an arbitrary pressure and in a given time. Two related materials will, therefore, have equal viscosities at their respective tack temperatures, or

$$\log \eta_1 = \log \eta_2 = A_1 + CM_1^{1/2} + B/T_1 = A_2 + CM_2^{1/2} + B/T_2 \qquad (2)$$

From this equation we have a way of predicting a tack temperature, $T_2$, if $T_1$, $M_1$, and $M_2$ are known. This consideration is similar to Tuckett's isoelastic temperature considerations of polymers *(10)*.

It is also known that for polymers of low molecular weight, the Staudinger equation is a reasonable approximation relating viscosity of solutions to solute molecular weights, or

$$[\eta] = K_1 M \qquad (3)$$

where $[\eta]$ is the intrinsic viscosity and $K_1$ is a constant. Substituting (3) in (2):

$$\frac{C}{K_1^{1/2} B} [\eta]_1^{1/2} - [\eta]_2^{1/2} = \frac{T_1 - T_2}{T_2 T_1} \qquad (4)$$

From this it may be concluded that the polymer with the higher intrinsic viscosity should have the higher tack temperature and tend to have lower adhesion to a substrate.

In addition to the viscosity requirements for adhesion there are electrical requirements. The product $\mu_1$, $\mu_2$, is a measure of the inner attraction of dipoles *(3)* and $\epsilon'$ is a measure of the polarizability of a material *(11)*. It has been shown that for an electrically conducting surface, the force of attraction of a dipole can be obtained by substituting in place of the surface a mirror image of the dipole in the surface with the poles reversed *(12)*. The value for the attraction potential between a surface and a dipole is proportional to $\mu^2$ (or the van der Waals' constant $a$). Apparently Ostwald *(13)* has modified this conception by dividing $\mu^2$ by $\epsilon'$, the dielectric constant. Thus $\mu^2/\epsilon'$ becomes a measure of the so-called "mirror-image force," the force with which a dipole is attracted by its induced mirror image *(14)*. A plot of tack temperature vs. $\mu_1 \mu_2/\epsilon'$ for the adhesion of high polymers to any substrate would expectedly give rise to an adhesion area outside of which no adhesion would be observed for any polymers not bearing OH or COOH groups.

## Adhesion as a Combination Sorption-Viscosity Phenomenon

In view of the above interpretation of the influence of temperature on polymer chain mobility one may say that a dipole within a polymer must first be oriented favorably with respect to the cellulose substrate. It is believed that with increasing temperature the micro-Brownion movement of the chain segments to which substituent groups are attached would increase, since such movement requires an activation energy of fluidity. Hence, with increasing temperature a larger and larger percentage of polar groups in the vicinity of the interface layer would be permitted to orient and form dipole bonds with the active centers on the cellulose. Further sorption of dipoles will thus be permitted. This process involves a heat of sorption. The heat of sorption, $H_s$, will be the difference between a heat of fluidity, $H_1$, given by *(15)*

$$\frac{d \ln \phi}{dT} = \frac{H_f}{RT^2} \qquad (5)$$

where $\varphi$ is the reciprocal of viscosity $\eta$ (see integrated form, equation 1), and a heat of adhesion, $H_a$, given by

$$\frac{d \ln c}{dT} = \frac{H_a}{RT^2} \qquad (6)$$

where $c$ is the concentration of dipoles in contact with the cellulose substrate required to give a constant amount of adhesion (the isostere).

Sorption is an exothermic process which decreases with increasing temperature, while fluidity is an endothermic process which increases with tempera-

ture. Therefore, the temperature dependence of adhesion, i.e., whether adhesion increase or decreases with temperature, depends on the relative magnitudes of molar heats as given by

$$H_a = H_s + H_f \qquad (7)$$

If the heat of sorption derived from the sorption process is less than the heat of fluidity of the polymer at the interface the net value of $H_a$ will be opposite in sign from $H_s$ and adhesion will increase with increasing temperature. This is true experimentally for vinylchloride-vinylacetate-maleic anhydride polymer *(16)*.

Examples of such behavior in classical sorption experiments are rare but not without precedence. The sorption of water and more especially the sorption of liquid mercury by charcoal are effected in this unusual way with increasing temperature *(17)*.

To illustrate the sorptive nature of the adhesion process, it was shown previously *(16)* that for a series of mixtures of vinyl polymer and vinyl-maleic anhydride copolymer a parabolic or Freundlich-type sorption isotherm was observed when adhesion was plotted as a function of carboxyl concentration in the coating. The data could be represented by

$$\text{Heat Seal} = K(\text{COOH})^n_\eta \qquad (8)$$

where n has a value of about 0.6. The exponent 0.6 is very close to the theoretical value of 0.67 which is predicted by Gyani *(18)* for surface sorption. Here the subscript $\eta$ is used to designate constant melt viscosities for all polymers in the series.

The right to express adhesion as a function of carboxyl concentration is supported by the experimental fact that compositions of vinylite copolymers containing no carboxyl groups exhibit little or no adhesion to cellulose whereas those containing only small amounts exhibit remarkably high adhesion (100 fold increase).

Data of the sort discussed above may be employed for the calculation of the heat of adhesion, which is primarily a sorption process influenced by viscous flow. The integrated forms of equations 5 and 6 combine to give

$$H_a = \frac{RT_1 T_2}{T_1 - T_2}\left(\ln\frac{c_2}{c_1} - \ln\frac{t_2}{t_1}\right) \qquad (9)$$

where $c_1$ and $c_2$ are the concentrations of carboxyl at temperatures $T_1$ and $T_2$ and $t_1$ and $t_2$ are related to $\varphi$, the fluidity by the equation

$$\ln t = -\ln \phi - \ln C^1 \qquad (10)$$

where $C^1$ is the constant of integration depending on experimental conditions at which the viscosity was measured. The values found experimentally were

$H_a = +12{,}500$ calories per mole
$H_f = +30{,}000$ calories per mole
$H_s = -17{,}500$ calories per mole

on the assumption that the kinetic unit of fluidity and the static unit of sorption were the same. The units of motion and sorption involved may be several (6 to 18) carbon atoms of chain length *(9)*.

The effect of a polar plasticizer on adhesion would be to lower the activation energy for viscous flow and thus tend to increase the adhesion by decreasing the endothermic energy requirements for the adhesion process.

## Generalized Concept of the Adhesion of Polymers to Cellulose

Generalizing, the adhesion of high polymers to cellulose involves first a rate phenomenon. Large polymer molecules migrate from solution or in a melt by macro-Brownian movement to the cellulose interface. By micro-Brownian movement, involving configurational changes along chains, chain segments become adjusted to polar constituents of the base material. In the absence of a vehicle, chain segments approach surfaces only in spots by macro-Brownian movement. With pressure and local fluidity resulting from heating, chain segments may approach quite closely to the interface. This calls for polymers having relaxation times of $10^{-7}$—$10^{-4}$ second *(4)*. The second process involves sorption phenomena. When segments are with 5A secondary forces begin to operate, a spectrum of forces ranging from dispersion forces of the order of $10^2$ calories per mole to hydrogen bonds of $10^4$ calories per mole. Such forces involve (a) dipole-dipole attraction, (b) induced dipole-dipole attraction, (this induction may occur between a strong dipole, for example, —$NO_2$, and a polarizable segment or radical, including points of unsaturation or aromaticity), and (c) van der Waals attraction, as in polythene and polystyrene (attraction depends upon two virtual oscillators giving rise to a resonance type of bond). The requisite for permanent attraction or adhesion is that the material wet the substratum. DeBruyne *(19)* has enunciated the rule that strong joints can never be made between polar and non-polar substances. Adhesive materials must show a certain resistance to forces of stress and sheer if any attempt is made to separate them from the base sheet. If the degree of polymerization is too low, poor adhesion results through chain slippage; if too high the viscosity is great, and the material is tough and hard. A degree of polymerization of 50 to 300 is best *(3)*. If the polymer coating material is not tractable an "outer softening" may be expected by (1) increasing the temperature, (2) by adding a plasticizer whose molecules penetrate the macromolecules and increase chain segment mobility by saturating internal chemical forces. Both effects tend to increase adhesion to cellulosic surfaces. An "inner softening" can also be utilized: substituting highly mobile links, such as acetate, for some rigid ones, as in copolymerized vinylidene chloride, will render the polymer adhesive to cellulose.

The use of higher temperatures in bonding two coated cellulose surfaces is similar to the effect of a plasticizer or solvent but is much less efficient in promoting adhesion to cellophane.

## Literature Cited


1. McBain, J. W., in Alexander, J., Colloid Chemistry, Vol. I, pp. 11-24, The Chemical Catalog Co., Inc., New York, 1931.
2. Hildebrand, J. H., Solubility of Non-Electrolytes, pp. 77-92, Reinhold Publishing Corp., New York, 1936.
3. Mark, H., Physical Chemistry of High Polymeric Materials, pp. 81-115, Interscience Publishers, Inc., New York, 1940.
4. Josefowitz, D., and Mark, H., *India Rubber World* 166, 33 (1942).
5. Francis and Wade, U. S. pat. 2,353,717 (1944).
6. McLaren, A. D., Unpublished data.
7. Hauser, P. M., and McLaren, A. D., Industrial and Engineering Chemistry, 1947 (in press).
8. Clash, R. F., and Rynkiewicz, L. M., *Ind. Eng. Chem.* 36, 279 (1944).
9. Flory, P. J., *J. Am. Chem. Soc.* 62, 1057 (1940).
10. Tuckett, R. F., *Trans. Faraday Soc.* 38, 310 (1942); 39, 158 (1943).
11. Fuoss, R. M., The Chemistry of Large Molecules, New York (1943).
12. McBain, J. W., The Sorption of Gases by Solids, London (1932).
13. Ostwald, W., *J. Oil Color Chem. Assoc.* 22, 34 (1939).
14. Moll, *Kolloid Zeit.* 76, 200 (1936).
15. de Guzman, J., *Anales soc. espan. fis. quim.* 11, 353 (1913).
16. Hofrichter, C. H., and McLaren, A. D., *Ind. Eng. Chem.*, 1947 (in press).
17. Coolidge, A. S., *J. Am. Chem. Soc.* 49, 708, 1949 (1927).
18. Gyani, B. P., *J. Phys. Chem.* 49, 442 (1945).
19. DeBruyne, N. A., *Flight*, p. 51 (Dec. 28, 1939).

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# Spot Conversion for Adjustment Speed*

By W. R. Hough[1] and J. L. Van Nort[2]

**Abstract**

*Adjustable speed contributes to economical paper and paperboard production by making it possible to operate at the optimum speed for a given weight. It is also of value when it is necessary to regulate machine speed to avoid operating difficulties caused by nonuniform stock.*

*As operating speeds on processing equipment are pushed to higher levels to increase production and reduce costs, there is an increasing emphasis being placed on the smoothness and uniformity of acceleration and deceleration.*

*A small conversion unit installed at the machine to be operated—spot conversion—requires less maintenance than a single large generating unit upon which the operation of the entire mill depends.*

*The basic principle employed in the spot conversion drive is variable voltage direct current. The basis elements of this system are: (1) a unit to convert alternating to direct current, (2) a source of excitation which can be controlled for obtaining a variable d.c. voltage, (3) a d.c. motor receiving power from the conversion unit, and (4) suitable contro for starting, stopping, and controlling the speed of the motor.*

*Application of variable voltage drives is not confined to sectional paper machine drives and supercalenders. Other applications include winders and rewinders; variable output pumps; mixers; laminating, corrugating, and coating machines; washers and filters; log conveyors; pulp grinders; and machine tools.*

The need for adjustable speed in the paper industry as well as in most other processing industries stems from a universal demand, everywhere apparent today, for more and more production—from old as well as new equipment—without increasing costs or decreasing quality.

What adjustable speed can contribute to economical production is, of course, most easily recognized where the process is one which concerns a wide range of grades or weights of products. Take, for example, the formation and drying of the sheet on a paper machine. It affords an excellent demonstration of how the availability of adjustable speed promotes economical production. Obviously, if a paper machine is designed to have a maximum drying capacity, which will producte a 30-pound sheet at 1000 feet per minute, it would be limited to a lower speed in producing a 75-pound sheet. The ability to operate at the optimum speed for the weight of sheet to be run will result in the most economical production.

Another instance of the value of adjustable speed for economical production is where the characteristics of the material being processed change to some extent from day to day, requiring more delicate manipulation at certain times. In other words, while ostensibly the same material is being handled at all times, there is enough variation in the product to make it impossible upon occasion to run it at full speed without encountering breaks, poor finish, or other defects avoidable at lower speeds.

The contribution of adjustable speed to the control of quality has equally interesting possibilities. For instance, in a supercalender application, the speed and pressure with which the sheet is run through the stack creates heat. Excessive speed and pressure resulting in excessive heating will cause undue blackening of the paper and damage to the fiber rolls. The proper combination of speed and pressure is necessary to obtain the required quality. With adjustable speed available, a satisfactory balance can be struck between top quality and top speed.

In almost all processing machinery, it is necessary from time to time to accelerate and decelerate. This may be necessary because the machine has to be reloaded—provided with a new batch of raw material, such as a new roll for a calender—or it may be because the machine has to be unloaded—a roll of the desired size removed from the finishing end of the equipment. In other words, even when the operating speed of the machine is predetermined and essentially fixed, the requirements to accelerate to operating speed and decelerate to rest from operating speed may still be faced.

As operating speeds on processing equipment are pushed to higher and higher levels to increase production and reduce costs, there is an ever-increasing emphasis being placed on the smoothness and uniformity of acceleration and deceleration. In many cases, particularly those involving the processing of a light or thin web of material, it will be found that jerky acceleration or severe stopping result in breaks and substandard finish of material. And, regardless of any other causes, smoothly controlled acceleration and deceleration result in far less mechanical abuse of the apparatus.

With due regard for the work of eminent engineers who have devoted themselves to the problem of securing adjustable speed for an a.c. power source, there has not yet appeared any solution that in anywise approaches the flexibility, simplicity, and economy of the variable voltage method. Even in those European countries where, because of limited material resources, more has been done than here in exploring the possibilities of adjustable speed from a.c. circuits, there is reported a very definite trend toward the use of variable voltage control.

Of course, a large plant having d.c. distribution could be considered as an example of one way to solve securing adjustable speed from a.c. power. Here alternating current generated in the plant's own powerhouse or purchased from a central station is converted to direct-current and distributed throughout the mill. Adjustable speed d.c. motors placed out on the processing machinery throughout the plant could be assumed to provide the answer to adjustable speed with which to meet the requirements of quality control and economical production.

However, paper mill engineers in their progressive thinking recognize that for large processing equipment, such as a high speed paper machine, it is uneconomical, if nothing else, to attempt to operate a number of 200 to 300 h.p. motors from a 250-volt shop supply with conventional contactor starters, etc. They realize the desirability of providing a conversion

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unit in the form of a motor generator set whose sole purpose is to provide adjustable voltage, or variable voltage if you wish, to the several machine motors. Not only are large accelerating contactors and accelerating resistance eliminated, but there is provided a wider range of adjustable speed than could be obtained from a constant d.c. potential. Further, precise control of operating performance may be accomplished more readily.

The good judgment of these paper mill engineers has been thoroughly demonstrated as year after year the top operating speeds of paper mill equipment are pushed higher and higher to obtain more production at reduced costs.

In this country, as elsewhere, a great deal of our engineering is necessarily influenced by previous experience. Many times an engineer asks himself, "If the solution reached on machine 'X' in the machine room is giving such excellent results, why isn't the same solution applicable to the new machine proposed for the finishing room or stock preparation plant. Granted that the finishing room auxiliary machine requirement is much smaller than the successful application in the machine room, fundamentally do not the same requirements exist on both?"

That is exactly the logic which has made variable voltage control an accepted tool in all industries for all types of processing machinery requiring adjustable speed for any of the reasons already enumerated. Further investigations have revealed many advantages aside from the knowledge superiority of performance. For instance, a small conversion unit installed at the machine to be operated—spot conversion—obviously requires considerably less maintenance that a single large generating unit upon which the operation of the entire mill depends. However, when the machine with which the spot conversion units is associated is not in production, the latter can be turned off after which it requires zero attention. By contrast, a central generating unit requires constant attention, and probably must have more care when it is operating only 10% loaded than when it is carrying its full load.

Many large organizations have made studies of the relative cost of generating and distributing direct currect as compared with distributing and converting alternating current for adjustable speed purposes at an individual machine. In making such a study the analyst frequently faces the statement, "There is at present enough or more than enough direct current already available throughout the plant."

Such a situation must be evaluated from two points of view: Of course, the fact that the original installation cost 'X' dollars, a part of which should be charged against operating any new machine, cannot be ignored. However, one should certainly refrain from concluding that the plant has reached its peak of production, will never require any additional direct current capacity and therefore has available in the margin above present requirements all the direct current that will ever be required. Such a conclusion ignores the fact that expansion is actually under way and is by no means the last that may be undertaken. Therefore, whether there already exists sufficient direct current for immediate purposes is not of itself the only criterion. First, because it is an economically unsound premise and second, because in so many cases it does not give the full answer to the requirements of modern machinery.

When the paper mill electrical engineer originally saw fit to provide a conversion unit for his paper machine, he placed the motor-generator set along with its control in a motor room where he could keep the apparatus free of dirt, enclosed it to prevent accidents, and put it under the supervision of a competent man.

The logic of this arrangement was so apparent that it is carried over into the design of today's individual conversion equipment.

### Spot Conversion Drives

The basic principle employed in the spot conversion drive is variable voltage direct current. The basic elements of this system are four in number: (1) a unit to convert alternating to direct current, (2) a source of excitation which can be controlled for obtaining a variable d.c. voltage, (3) a d.c. motor receiving power from the conversion unit and (4) suitable control for starting, stopping, and controlling the speed of the motor.

The conventional type of conversion unit uses a squirrel cage induction or synchronous motor to drive a regular d.c. generator and exciter. The latter supplies excitation to both the main generator and the d.c. motor driving the machine. The output voltage of the main generator is varied by rheostatic control of the excitation.

Another type of spot conversion equipment has recently been introduced which makes use of electronic equipment. The conversion unit is a grid controlled rectifier, the output of which is supplied to the armature of the d.c. motor driving the machine. The excitation is supplied by another rectifier. This may be noncontrolled rectification—with the excitation voltage controlled by a rheostat in the output circuit of the rectifier—or it may be grid-controlled rectification, giving controlled output voltage.

Adjustable speed for variable voltage spot conversion drive is based upon the fact that a d.c. motor supplied with constant excitation for its fields will vary in speed directly with the voltage supplied to its armature, minus the *IR* drop in the motor armature. The system has been used for years on large and expensive machines where precise speed control was an important operating consideration. An important feature of the variable voltage drive is that several d.c. motors may be operated from the same conversion unit, each with speed characteristics approximately identical. This principle has been widely used in connection with sectional drives on paper machines. Individual motors on each of the main sections of the machine are controlled together to maintain the speed of all sections in approximately constant relationship.

Today the many modifications and refinements possible with a system of variable voltage make it applicable to every job where there is an advantage in having operating control of machine performance. This is as true of a 1-hp. pump application as it is of a 600 hp. supercalender installation.

In its simplest form the useful speed range of 10:1 with satisfactory operating characteristics is readily obtainable. Over this range of speed the torque characteristics are such that the d.c. motor is capable of producing a constant output torque. The principal limitation toward extending this speed with the simplest type of equipment is that at low speed change of the motor from no load to full load will be a relatively large percentage of full load speed. This, however, can quite readily be improved and the range of usefulness increased to 20:1, 30:1, or even higher, by including regulating means or what is known as *IR* drop compensation to reduce the speed drop between

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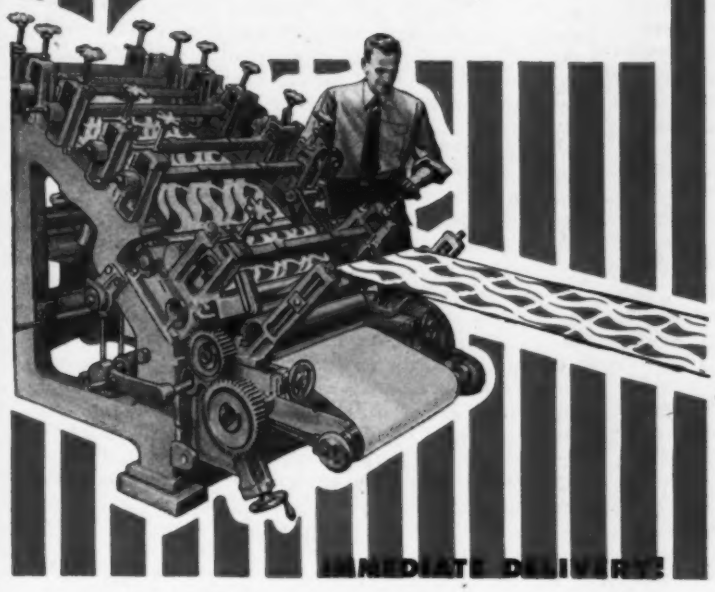

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### Phenolic Resins Aid in Weather-Proofing Plywood

Phenolic adhesives, produced in a variety of forms, are widely used in the plywood industry. Phenol, or mixtures of phenol and cresylic acid, when reacted with formaldehyde in the presence of caustic soda as a catalyst, produce resins of particular interest to plywood manufacturers. So called "exterior" plywood which must be resistant to almost all types of weathering are made with such phenolic adhesives. Water-soluble phenolic resins are also used extensively in the manufacture of plywood because of their economy in use and freedom from fire hazard.

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no load and full load at low speeds. The motor is still capable of maintaining constant output torque although continuous operation at very low speeds may produce overheating of the motor unless auxiliary ventilation is supplied. Where this is a necessary consideration, auxiliary ventilation can readily be applied.

With the electronic conversion equipment, *IR* drop compensation is necessary for successful operation and is included in the voltage control circuit. Here again the wider range can be secured by additional refinement in the regulating means. In either system the speed range can be extended by introducing field weakening control of the d.c. motor to get speeds higher than obtained at full operating voltage and with full field strength of the motor. An extension of 2:1, 3:1, or even 4:1 in the speed range can sometimes be secured. The principal limitation is usually the top operating speed permissible with the motor.

Over the range of speeds secured by motor field weakening a motor is capable of producing a constant horespower output since its output torque varies inversely with its speed. An example of this wide range of speed control is the supercalender drive. Satisfactory operation must be secured at 50 feet per minute for threading purposes on a machine that may have a top speed of 2,000 feet per minute—or a total speed range of 40:1. In this case, a speed range made possible by voltage control with *IR* drop compensation would be on the order of 25:1 for satisfactory operation at the low threading speed. An additional speed range of approximately 1.6:1 could be obtained by motor field weakening control, giving a total range of speed of 40:1. Other examples of different degrees of voltage and field control covering wider ranges of speed could be cited.

### Acceleration and Deceleration

One of the most important characteristics of variable voltage drives is the control of the rate of acceleration and deceleration which is so easily accomplished. Likewise the increments of acceleration and deceleration can be made small to produce smooth changes up or down as well as to provide a wide selectivity of permissible operating speeds.

As the speed of machines and of processing material have increased, it has become important that neither machine nor material be damaged during the accelerating or decelerating periods. In both rotating and electronic systems, the output voltage of the conversion unit is usually controlled through a rheostat handling relatively small current. In the rotating system, the rheostat may handle either the field curren' of the generator or, if this is too large for economic consideration, the field current of the generator's exciter. In either case it is a matter of a very few amperes. In the electronic system, the rheostat will handle the current in the grid circuit of the grid control rectifiers which is a matter of milleamperes.

The important point is that a rheostat to handle small currents can readily be built with a multiplicity of steps thereby giving small increments in speed change between steps. Furthermore, the rheostat may be either manually or motor-operated so that the rate of change, and therefore, the rate of acceleration or deceleration, is conveniently controllable within wide limits.

In acceleration, the important consideration is that it be smooth whether fast or slow. It is frequently accomplished with a motor-driven rheostat containing as many as 120 steps or increments of speed change and with an acceleration time adjustable over a 5:1 range, for example 8 to 40 seconds. A recent refinement which has been introduced is time limit control of the field circuits by electronic means.

For normal deceleration the process is simply reversed. However, in the event of an emergency, the important consideration is to stop as quickly as practicable (1) to reduce the amount of broke, (2) to reduce the possibility of damage to the machine. In this case an emergency stop will provide regenerative braking either into the generator or a resistor or both which still gives a smooth deceleration but reduces the time of deceleration to the order of 2 to 4 seconds from maximum speed to stop.

Frequently, a further requirement in processing material is that the web of material be maintained under tension during acceleration and deceleration—with the tension controlled to approximately the same value as is to be maintained during normal running. Here again this involves introducing regulating means (1) to control tension during normal operation, and (2) to modify this tension control to compensate for inerita or $WR^2$ of the machine in supplying the necessary torque for acceleration and deceleration. For example, in accelerating a machine of large $WR^2$ which is processing a web of material, two increments of torque must be provided, (1) the torque required to process or maintain tension in the material and (2) the torque required to accelerate the inertia of $WR^2$ of the machine. Once the machine has reached its operating speed the torque requirement is simply that required to overcome the friction of the machine and process the material. This is accomplished by introducing into the regulating means a compensation or increment of torque for accelerating added to the torque required for overcoming friction and processing the material.

### Synchronization

When a machine has a motor drive consisting of two or more motors driving various of its parts or components, it is usually necessary that the speeds of the individual motors be synchronized so that they maintain a uniform speed relationship at all times. Inherently the characteristics of variable voltage provide for approximate synchronization over the range of voltage control. Several degrees of refinement can be included depending upon requirements. Where a close approximation rather than an absolute speed synchronization is all that is required, introduction of *IR* drop compensation in the individual motors is frequently all that is needed.

Where the torque requirement of the processing material is large relative to the frictional torque requirements of the machine, regulation through current control of the individual motors may be entirely adequate. However, when the torque requirement of the processing material is small compared with the frictional requirements of the machine and a continuous web of material is being processed, then absolute synchronization with actual motor speed as a reference is usually required. An example of this is the sectionalized paper machine drive. By using as a reference the speed as a master section, several regulating means can be introduced so that the speeds of individual motors bear an absolutely constant relation to that of the reference speed. Likewise, compensation may be introduced to change the ratio to be maintained between the speed of the individual motor and the reference speed. Such compensation may be necessary because of stretch or shrink of the material being processed.

### Control Characteristics

The variable voltage system may be amplified to include controlled characteristics of various degrees and various types. Basically, these fall in four classifications—control of (1) current, (2) voltage, (3) speed, or (4) rate of change of speed. It is largely in the precise control of these 4 elements that the rotating regulators, instrument regulators, and electronic regulators are used.

It is possible, for example, that the control of the acceleration may be a function of time, of current, or the linear relationship of change of speed to time meaning equal increments of speed change per unit of time. Sequence operation or programming in which an operating cycle for a machine may be set up in advance and performed automatically, is readily obtainable.

### Typical Applications

The wide range of usefulness of variable voltage drives is not necessarily confined to the larger and better known applications, such as sectional paper machine drives and supercalenders. Other applications and the particular characteristics of the variable voltage system should certainly include the following:

1. Winders and rewinders. Smooth acceleration and deceleration, tension control, synchronization.
2. Variable output pumps. Speed range in small increments and, in some cases, precise speed control.
3. Mixers for combining various quantities of different ingredients. Speed range in small increments with adjustment of speed of individual motors so that the ratio of the components in the mixture can be controlled and maintained.
4. Laminating, corrugating, or coating machines. Synchronization of the various parts of the machine to obtain uniform quality of the laminated material.
5. Washers and filters. Speed range and control of speed for output control.
6. Log conveyors—acceleration and deceleration and rate of handling.
7. Pulp grinders, feed. Speed range, optimum speed for maximum capacity.
8. Machine tools. Speed range, and close increments of speed control.

### Other Considerations

One of the considerations which frequently develops as a result of experience with the great range and flexibility provided by variable voltage drives is the simplification of machine design through the elimination of gears, belts, pulleys, and clutches. An outstanding example in the paper industry is the supercalender where with older types of drives some sort of speed changing mechanism had to be provided to bridge the gap between threading speed and operating speed. In some cases this was done with two motor drives, with clutches or over-running clutches, with gear shifting mechanism, or with other combinations of belts, pulleys, and clutches. The same is true of winders where slip clutches, once used to approximate tension control, can now be eliminated. In machine tools, a multiplicity of gear changes has in many cases been entirely eliminated or reduced to a single gear change.

Increased production has been achieved in a number of ways. One, of course, has been through the ability with a variable voltage drive to operate at the optimum speed. Others have come about through the reduction in down time and broke, through the ease of speed selection and speed change, and through the close control of acceleration and deceleration which is possible with this type of drive. Production has also been increased by these "spot conversion" units through the flexibility they have introduced into mill layout and arrangement of equipment.

A much superior job of mill layout, for example, can be done when spot conversion rather than plant-wide d.c. distribution is the accepted means of securing adjustable speeds. When it is necessary to distribute only a.c. power, a completely adequate job can be done to cover all sections of the mill. From then on the location or relocation of all but the largest machinery and equipment can be handled without concern for the availability of power. In other words, the flow of material and other purely production considerations can be the determining factors.

The ability to install spot conversion equipment at the point of use has largely influenced its design. Proper enclosures, provision for filtered ventilation, ease of installation and special provisions for maintenance have all been influencing factors. Provision in special cases for building the equipment into the machine itself has also been an influencing factor in its design.

The most satisfactory "package" has been found to be a cabinet ventilated with clean air through filters by a fan operated as an integral part of the variable voltage equipment. The enclosure is under pressure which tends to exclude dirt quite in the same manner as the atmosphere is maintained in a motor room.

The spot conversion unit in the base is factory-assembled with the control and all inter-wiring completed. The a.c. contactor for establishing connection to the a.c. power source is within the enclosure as well as the various relays and resistors required for the variable voltage control of the conversion unit itself. It is literally a packaged item which can be placed on the "spot" most convenient to the machine it is to serve. Its nicety of performance is comparable with that of a 1000 kw. motor-generator set in a motor room. Certain design features have reduced the number of control items and the number of moving parts.

Whether the spot conversion unit be the rotating or electronic type makes little or no difference in the logic of its use, although for certain applications one may be better than the other.

A most important consideration is that the drive as a packaged spot conversion unit minimizes the engineering to be supplied by the user and at the same time reduces greatly the installation cost. From a maintenance standpoint its costs are again reduced, due to the accessibility of the entire unit and the fact that it is mechanically protected from injury.

From an appearance standpoint the engineering approach has paid its respects to precedent wherever possible. The general acceptance in the industry of metal clad switch gears, dead front controllers of all descriptions and enclosed apparatus was the guide for the enclosure provided on the drive. Whether it be a 1 h.p. or a 200 h.p. drive, we have tried to make it equally pleasing in appearance and able to blend harmoniously with the machine it serves or the background of the mill.

Because the spot conversion unit can be moved from "job" to "job" as the changing requirements of production may dictate, frequently a complete rearrangement of a mill in the interest of streamlined production can be achieved without any loss of installation dollars for the electrical interconnections between the converting unit and the control.

# Flow Method for Determining Water Vapor Permeability at 0°F.*

By Frederic H. Cherepow[1]

**Abstract**

*An adaptation of the isostatic method for determining gas permeability is used to measure water vapor permeability at 0°F.*

*Air, saturated with water vapor at 0°F., is passed at a known rate over one side of a series of test sheets held in a diffusion cell maintained at 0°F. Air, dried to eseentially 0% relative humidity at 0°F., is passed over the other side. The water vapor in each effluent air stream is continuously absorbed in desiccant and the amount determined gravimetically. Permeability is measured by the rate of gain of water vapor in the dry air. Comparison of total water vapor in both air streams on exit from the cell with theoretical amount entering the cell serves as a check on the accuracy of the determination. Test sheet areas up to 2283 square centimeters and test periods up to 24 hours or longer are used when testing sheets of low permeability.*

*Data obtained at 70 and 100°F. with the flow method compared favorably with comparative tests conducted in accordance with TAPPI standards T448 m-46 and T464 m-45. The method is suitable for determining water vapor permeabilities of commercially-used frozen food wrappers down to about 0.01 grams per square meter per 24 hours (dry vs. saturated conditions at 0°F.)*

The steady increase in the packaging of frozen foods in flexible sheet materials has stressed the need for a suitable method for determining the water vapor permeability of such materials at temperatures and humidities encountered in their use. It has been established *(1, 2)* that the permeability of a sheet material obtained at one set of temperature and humidity conditions does not necessarily establish a basis for predicting the permeability of that sheet at other conditions. It is recognized that a practical overall evaluation of packaging materials may be best obtained by actual packaging tests on the completed package, since such tests take into consideration all of the factors involved in a suitable package, e.g., seals, handling, machine workability, etc. However, it is often advantageous to evaluate each factor independently of the other.

Literature surveys *(3, 4, 5)* on the subject of water vapor permeability of flexible sheet materials contain many references pertaining to methods and apparatus for determining permeability, factors and mechanism of such permeability, and data on the actual permeability of such materials. Most of these references are concerned with measurements made at temperatures of 70°F. or above. There are comparatively few references to actual methods or data at conditions of special interest to the frozen food industry or its packaging material suppliers.

Tressler and Evers *(6)* described a cup method for determining the water vapor permeability of sheet materials at a temperature of —14.5°C. (6°F.). A test sheet (44 square centimeters area) was sealed with wax over a crystallizing dish, containing ice, and exposed to an atmosphere of 50% relative humidity at —14.5°C. The permeability was based on the rate of loss of water vapor during a storage period of 10 days with weighings made at semi-weekly intervals.

DuBois and Tressler *(7)* employed a modification of the above method in the evaluation of wrapping materials for frozen foods. The modification based the permeability on the loss in water vapor through a test sheet, having an area of only 12.5 square centimeters, during a period of 7 days at the above mentioned storage conditions. No mention is made of weighing to constant rate of loss. The actual test sheet areas in both the original and modified methods appear to be small based on the present TAPPI standard methods *(9, 10)* which suggest sheet areas of at least 50 square centimeters for tests conducted at much greater vapor pressure differences.

Rabak *(8)*, in similar studies, devised a cup which employed a test area of 141 square centimeters, wherein the test sheet was clamped between rubber gaskets. Permeability was based on the loss in weight of the assembly when the cell contained ice, also, on the gain in weight when the cell contained calcium chloride desiccant. External humidity conditions surrounding the cup were not known but were judged to be those existing under average commercial frozen food lockers at temperatures of 0°F. and 15°F. The loss or gain was determined on the basis of weighings made prior to and following a 6-day exposure period. No mention is made of weighing to constant rate of change in weight in either case.

More recently, the Packaging Institute adopted a cup method *(11)* as a standard method for determining water vapor permeability of sheet materials at 0°F. In this method, a test sheet (area of 133 square centimeters) is sealed with wax in a shallow aluminum cup containing anhydrous calcium chloride, and is then stored at 0°F. in a specially designed cabinet containing coarsely-cracked ice. No provision is made for circulation of the air on either side of the test sheet. Following a conditioning period of 4 days, weighings are made at 28 day intervals until a constant rate of gain has been established. Inasmuch as the aluminum cups are weighed at room temperature, careful and lengthy techniques are required in conditioning these cups from 0°F. to room temperature conditions. Alternating exposure to these extremes of temperature may subject the test assembly to considerable stress and strain.

Doty, Aiken, and Mark *(2)* have reported results obtained over a temperature range of —10°C. to 80°C. using a modification of the method and apparatus developed by Schumacher and Ferguson *(12)*. In this method, the test sheet separates two evacuated compartments. Water vapor at a known pressure is introduced into one compartment. Permeation rate is established by the rate of water vapor

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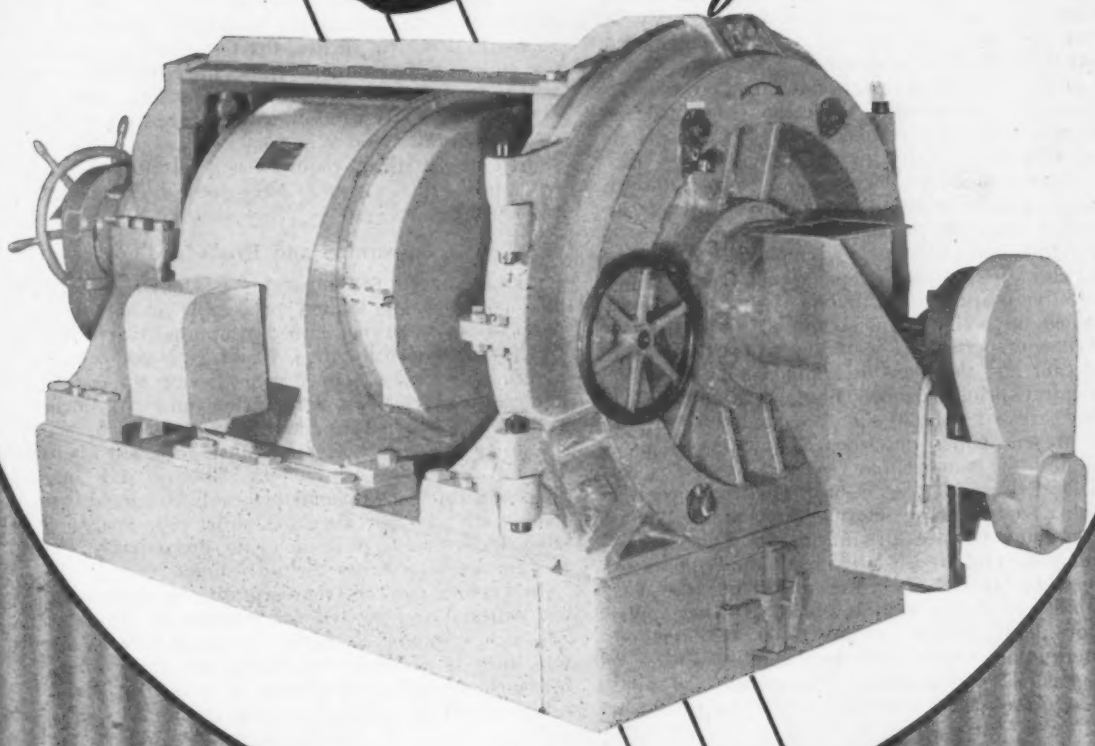
[1] Research Department, Marathon Corp., Menasha, Wis.

# Quality THROUGH Design



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pressure increase in the other compartment. Such a method permits the knowledge of the vapor pressure difference during the test, but does not provide for the circulation of the gas on either side of the test sheet.

Comparatively few investigators have approached the problem of permeability measurement based on the "flow" or "dynamic" technique wherein two streams of air containing different amounts of water vapor are circulated over opposite sides of the test sheet. Such a method appears to have certain advantages over cup methods in that (1) stagnation of the air on both sides of the test sheet is avoided, (2) it is possible to determine the average actual vapor pressure on both sides of the test sheet during the test, and (3) various methods of analysis may be used to determine the rate of water vapor transmission through the test sheet.

Edwards *(13)* described a flow method for determining the permeability of leather in which the sample was held in a diffusion cell and continuous streams of moist and dry air maintained on opposite sides of the test sheet. Drying tubes were employed to measure gravimetrically the amount of water vapor permeating from the moist to the dry side.

Lishmund and Siddle *(3)* employed a similar method for determining water vapor permeability of protective coatings. Continuous air movement was maintained on both the moist and dry sides of the test sheet and permeated water vapor was absorbed in desiccant and the mass determined on a sensitive quartz spiral spring balance. This method employed a test sheet area of only 20 square centimeters.

The present paper describes a flow method for determining the water vapor permeability of sheet materials at 0°F. (dry versus saturated conditions). It has also been used for determinations at other temperatures and vapor pressure differences. This method is an adaptation of the isostatic method and apparatus developed by Davis *(14)* for measuring the gas permeability of sheet materials and is a further application of his suggestion on the use of that method for determining water vapor permeability.

The principle of this method is essentially the same as that involved in the methods described by Edwards *(13)*, Lishmund and Siddle *(3)*, and Davis *(14)*. Air is saturated with water vapor at 0°F. and passed at a known rate over one side of a series of test sheets held in a diffusion cell maintained at 0°F. Air, dried to essentially 0% R.H. at 0°F., is passed over the other side. The water vapor which permeates through the test sheets from the moist air side is entrained in the dry air, absorbed in desiccant, and the amount determined gravimetrically. The water vapor remaining in the moist air on exit from the cell is similarly determined. Permeability is measured by the rate of gain of water vapor in the dry air. Analysis of the amount of water vapor in each effluent air stream permits the calculation of the vapor pressure difference across the test sheet. The absorption and subsequent weighings are made at room temperatures, hence, the test sheet assembly is not subjected to extreme temperature-humidity variations during the course of the test. The method is of particular interest in low-temperature studies where permeation rates tend to be very low, as only relatively short test periods are required as a result of the large test sheet area (up to 2283 square centimeters) employed.

### Apparatus and Procedure

A diagram of the apparatus is shown in Fig. 1. The apparatus is located preferably in a constant temperature room maintained at approximately 70°F.

The diffusion cell (Figs. 1 and 2) is composed of a series of stacked copper rings having internal and external diameters of 6⅛ inches and 6⅜ inches, respectively. It is designed to accommodate from one to twelve test sheets equivalent to a test area of 190 to 2283 square centimeters. The top and bottom rings are capped with end plates. Each ring is provided with a copper inlet and outlet tube at opposite sides. Baffles, soldered in each ring, properly distribute the air streams across the test sheets.

In loading the cell, representative samples of the test material are selected for testing and cut to size 7¼ inches square. A gasket for each side of each test sheet is prepared by cutting out the center of 7¼ inch squares of Parafilm (a rubber-wax film) using a circular template having a diameter of 6⅛

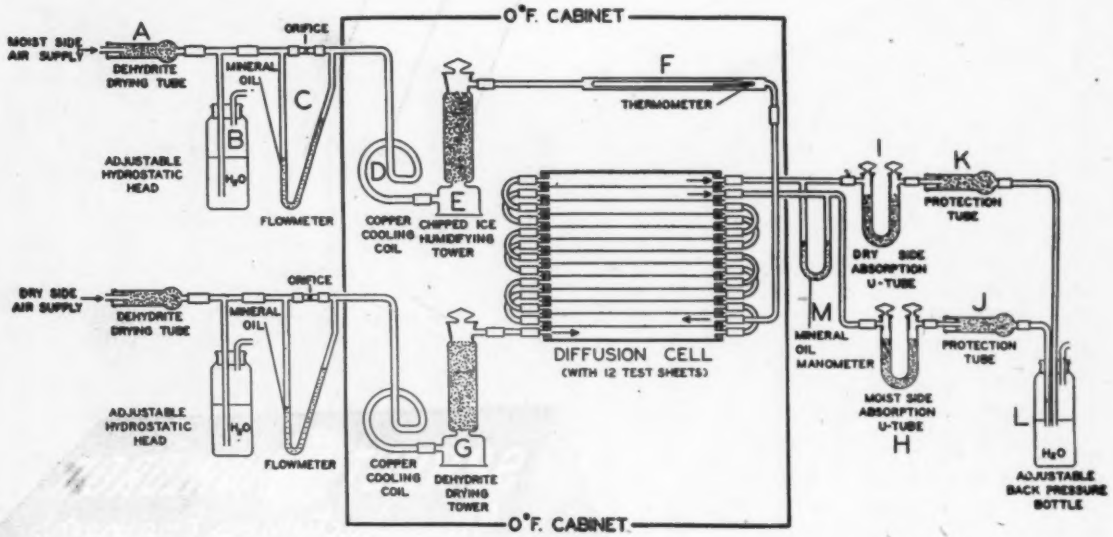
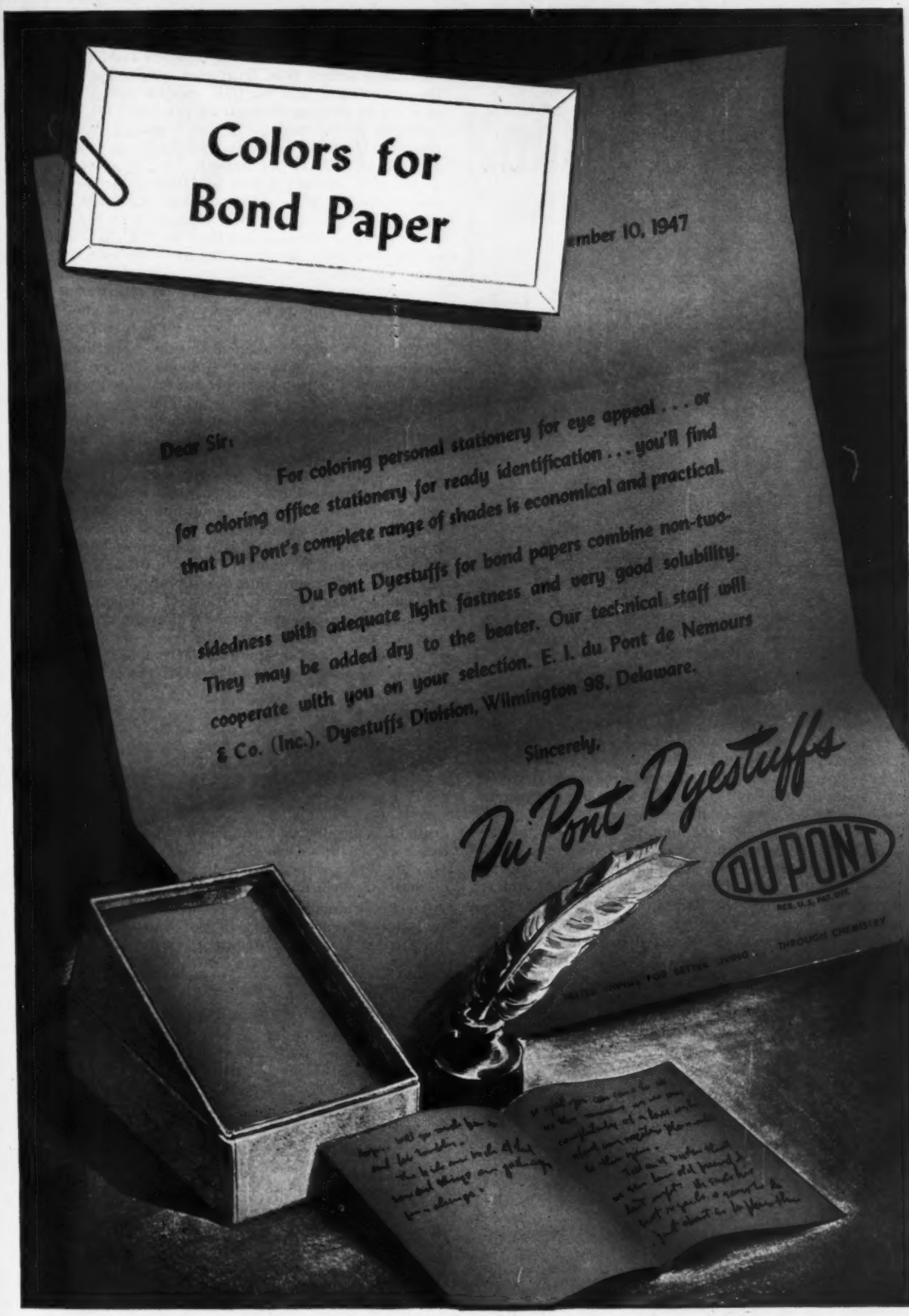



FIG. 1

**Apparatus for Water Vapor Permeability (0°F., dry vs. saturated conditions)**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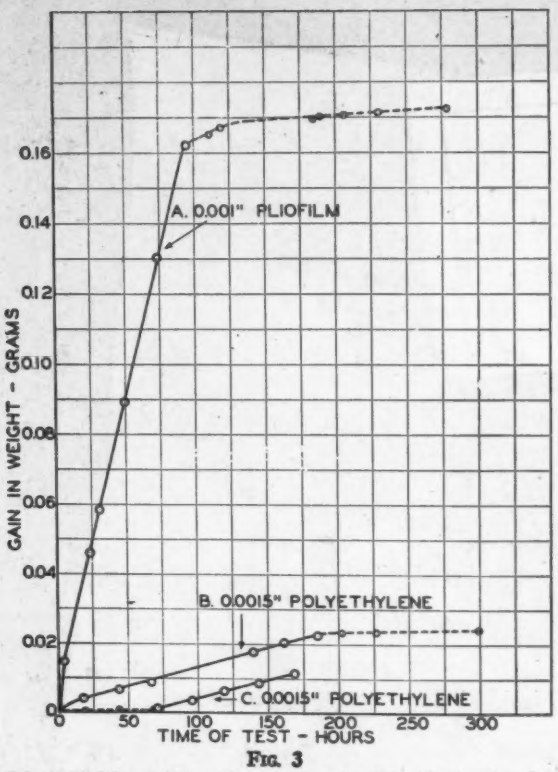


FIG. 3

Gain in Weight of Water Vapor in Dry Air Side. Blank values indicated by broken lines. Test conditions 0°F., dry vs. saturated. Area = 2283 sq. sm. Air Flows A, B, = 100 cc./min. C = 500 cc./min.

inches. The test sheets and gaskets are placed between each diffusion cell ring using care to avoid wrinkles. Normally twelve sheets are loaded into the cell, however, a fewer number may be used for materials having high permeability. The rings are so assembled that the copper inlet tubes on adjacent rings are separated by about 2 inches (Fig. 2) to alleviate interference in connecting alternate chambers in series.

On completing the loading of the sheets in the cell, it is compressed in a screw press to the maximum pressure obtainable with a 5-inch knurled knob using hand pressure only. Under such compression and at room temperatures, the Parafilm gaskets tend to flow slightly to effect essentially gas-tight seals. The alternate cells are then connected in series by means of glass tubing and heavy wall synthetic rubber tubing. This results in a two-sided system which permits a flow of moist air over one side of each test sheet and dry air over the other.

The assembly is then checked for leaks to the atmosphere by connecting the two sides of the system in series and applying about 2 inches of mercury pressure difference as indicated by a mercury manometer located between the inside of the cell and the atmosphere. No readable pressure drop in a period of 10 minutes indicates that the assembly is sufficiently gas tight to proceed with actual permeability tests. It is then placed in a cabinet maintained at 0°F. (±1°F.) and immediately connected to the moist and dry air supplies.

The air used in the moist and dry air streams may be obtained from any convenient compressed air source. For the moist air stream, the air is first passed through the drying tube (A) containing Dehydrite (anhydrous magnesium perchlorate) then adjusted to a flow rate of 100 cc. of dry air per minute at 70°F. by means of the adjustable hydrostatic head (B) and calibrated orifice type flowmeter (C). This air is then introduced into the 0°F. cabinet and precooled to 0°F. on flowing through copper coil (D). About 4 feet of copper tubing (¼-inch inside diameter) in the coil (D) will effectively cool the air at flow rates as high as 500 cc. per minute. The ice tower (E) in the 0°F. cabinet serves to saturate the air with water vapor at 0°F. Thermometer (F) enclosed in the glass tube indicates the temperature of the moist air prior to its entrance into the cell. The dry air side of the assembly is similar to the moist air side, except that Dehydrite drying tower (G) is used in place of the ice tower (E). The moist and dry air streams on exit from the cell are brought out of the cabinet into the room by means of copper or glass tubing.

Air flows are maintained during a preliminary flushing period of at least 6 hours to permit the cabinet and the test assembly to reach temperature equilibrium. Permeability determinations are then started by connecting weighed Schwartz U-tubes (H and I), containing Dehydrite, to the moist and dry air streams. After a convenient period of time up to 24 hours, the tubes are removed and reweighed to determine the amount of water vapor absorbed from each air stream. Successive determinations are made until the rates of gain in both U-tubes are constant. Protection tubes (J) and (K) containing Dehydrite serve to prevent the counter diffusion of water vapor from the atmosphere into the tubes (H) and (I). Adjustable back pressure bottle (L) can be adjusted to maintain isostatic conditions within the cell or impart a small total pressure difference on either air stream as indicated by the manometer (M). Permeability is calculated by the following formula:

$$\text{Water vapor permeability} = \frac{W - b \times 24 \times 10{,}000}{t \times a}$$

= grams per square meter per 24 hours

Where

$W$ = water vapor gain in grams from dry air side in time $t$

$b$ = water vapor gain in grams from a parallel blank determination

$t$ = test time in hours

$a$ = area of test sheets in square centimeters

Blank determinations are made by replacing the ice tower (E) with a Dehydrite drying tower similar to (G) and proceeding as in the case of an actual permeability determination.

The total amount of water vapor in both effluent air streams over a given period of time should equal the theoretical amount of water vapor entering the

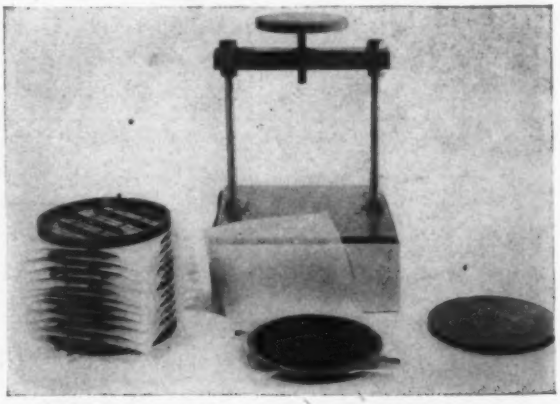

FIG. 2

View of Partially Assembled Diffusion Cell and Press

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TABLE I.—COMPARISON OF WATER VAPOR PERMEABILITY RESULTS AT 70° F. (50% R.H. VS. 0% R.H.) OBTAINED BY FLOW METHOD AND CUP METHOD (TAPPI STANDARD T448 m-46)

| Test Sample No. | Sheet Material | Thickness, inches | Flow Method: Test Area, sq. cm. | Flow Method: Air Flow Rates, cc./min. at 70° F. | Flow Method: Rate of Gain in Dry Air (g./hr.) | Flow Method: W.V.P., g./sq. m./24 hr. | TAPPI T448 m-46 W.V.P., g./sq. m./24 hr. |
|---|---|---|---|---|---|---|---|
| 1 | Polyethylene | 0.0015 | 1141 | 25 | 0.0030 | 0.63 | 0.81–0.84 |
| 1 | Polyethylene | 0.0015 | 1141 | 100 | 0.0031 | 0.65 | 0.81–0.84 |
| 2 | Polyethylene | 0.0015 | 1141 | 100 | 0.0030 | 0.63 | |
| 3 | Polyethylene | 0.0015 | 380 | 100 | 0.0012 | 0.76 | |
| 4 | Polyethylene | 0.0015 | 570 | 100 | 0.0016 | 0.66 | |
| 5 | Saran | 0.0013 | 762 | 100 | 0.0005 | 0.15 | |
| 6 | Saran | 0.0013 | 2283 | 100 | 0.0014 | 0.14 | 0.13 |
| 7 | Pliofilm | 0.0014 | 1141 | 100 | 0.0057 | 1.2 | 1.4 |
| 8 | Pliofilm | 0.0014 | 380 | 100 | 0.0021 | 1.3 | 1.3 |

cell in the moist air stream over the same period of time. Deviation from this indicates the presence of leaks in the system or a change in the test conditions. The theoretical amount of water vapor in the moist air stream entering the cell during a given period of time depends upon (1) the volume of dry air entering the ice tower (E), (2) temperature of the air and ice or vapor pressure exerted by the ice in tower (E), (3) barometric pressure, and, (4) the assumption that the air becomes completely saturated with water vapor.

The actual amount of water vapor in the moist air stream entering the cell may be determined experimentally by connecting a weighed Schwartz U-tube, containing Dehydrite, directly to the exit of the ice tower and determining the amount of water vapor absorbed over a given period of time. This should check with the above theoretical value and it serves as a measure of the efficiency of saturation of the air in the ice tower.

Sheets of high permeability may not permit the maintenance of the desired vapor pressure difference across the test sheets under the conditions described. In such cases, it is necesary to increase the flow rate of both gas streams and/or reduce the test sheet area by using fewer test sheets in the diffusion cell.

Glass or metal tubing should be used to connect the various parts of the apparatus. Butt connections are used in conjunction with heavy wall synthetic rubber tubing. Difficulty has been encountered in obtaining tight connections with natural rubber tubing since it tends to lose its stretch or elasticity at the low temperatures. Silicone stopcock grease may be used to facilitate making rubber tubing connections and may assist in improving the tightness of the seal.

Location of the entire apparatus in a constant temperature room maintained at approximately 70°F. provides a measure of convenience in calibrating the flowmeter orifices at the conditions in which they are to be used; effects more uniform control of air flow rates and of temperature within the 0°F. cabinet; and eliminates the need for extensive conditioning of Schwartz U-tubes prior to weighing, since the analytical balance is also located in the constant temperature room.

## Precision

Blank determinations should be made in the case of sheets of low permeability to improve the precision of the test. As high as 1 milligram increase in weight in the absorption tube in the dry air side in blank determinations of 24 hours duration has been found. Based on a fully loaded cell of twelve sheets, or 2283 square centimeter test sheet area, this value amounts to an apparent permeability of 0.005 grams per square meter per 24 hours. This is considered to be the sensitivity of the test. Duplicate determinations on the same test sample will usually agree within ±5%. Failure of the results to agree within this range usually indicates a change in the test conditions.

A constant check on the approximate accuracy of each determination is possible by comparing the total water vapor from both the moist and dry air sides with the theoretical value entering the cell in the moist air side, as discussed above. We have compared the theoretical value with the total water vapor in the effluent dry and moist sides and have found these to check within 10%. We have also found that the moisture pickup of dry air through the ice tower checks within 10% of the above theoretical value. Closer agreement than this might be attained with more accurate determination of the flow rates, temperature, and barometric pressure during the course of the test.

Other methods of analysis could probably be used in place of the gravimetric method described above to determine the amount of water vapor permeating through the test sheet. Such methods would include thermal conductivity, electric hygrometer, or gas interferometer. With these methods, however, calibration is required against a basic method such as the gravimetric. If the sensitivity of these methods of analysis is equal to or better than the gravimetric method, the convenience they afford might warrant their adoption.

## Results

In order to establish evidence to support the validity of the flow method for determining water vapor permeability at 0°F., comparative tests were made at 70°F. and 100°F. with the cup methods described in present TAPPI standard methods.

The data in Table I permit a comparison of the results obtained by the flow method and the cup method described in TAPPI standard method T448 m-46, employing the same samples of test sheets and test conditions of 70°F. and 50% R.H. vs. essentially 0% R.H. in each method. Excellent correlation is noted in the case of Saran and Pliofilm while fair correlation exists in the results obtained with polyethylene. The advantage of testing large sheet areas which are permitted by the design of the diffusion cell, is shown by reference to the rates of gain of water vapor in the dry air. The rates indicated, in the examples shown, are sufficiently high to permit test periods of relatively short magnitude, i.e., 1 to 2 hours, after equilibrium conditions have been reached. Again, reference to Table II shows that generally good agreement exists in the results of

TABLE II.—COMPARISON OF WATER VAPOR PERMEABILITY RESULTS AT 100° F. (90% R.H. VS. 0% R.H.) OBTAINED BY FLOW METHOD AND CUP METHOD (TAPPI STANDARD T464 m-45)

| Test Sample No. | Sheet Material | Thickness, inches | Flow Method: Test Area, sq. cm. | Flow Method: Air Flow Rates, cc./min. at 100° F. | Flow Method: Rate of Gain in Dry Air (g./hr.) | Flow Method: W.V.P., g./sq. m./24 hr. | TAPPI T464 m-45 W.V.P., g./sq. m./24 hr. |
|---|---|---|---|---|---|---|---|
| 9 | Saran | 0.0013 | 950 | 100 | 0.0067 | 1.7 | 1.1–1.3 |
| 9 | Saran | 0.0013 | 950 | 100 | 0.0053 | 1.3 | 1.1–1.3 |
| 10 | Saran | 0.0013 | 950 | 100 | 0.0071 | 1.8 | 1.2–1.4 |
| 10 | Saran | 0.0013 | 950 | 100 | 0.0066 | 1.7 | 1.2–1.4 |
| 11 | Saran | 0.0013 | 2283 | 100 | 0.0166 | 1.7 | 1.2–1.4 |
| 11 | Saran | 0.0013 | 2283 | 100 | 0.0147 | 1.5 | 1.2–1.4 |
| 12 | Polyethylene | 0.003 | 2283 | 100 | 0.0300 | 3.2 | 3.6 |
| 13 | Polyethylene | 0.003 | 2283 | 100 | 0.0305 | 3.2 | |

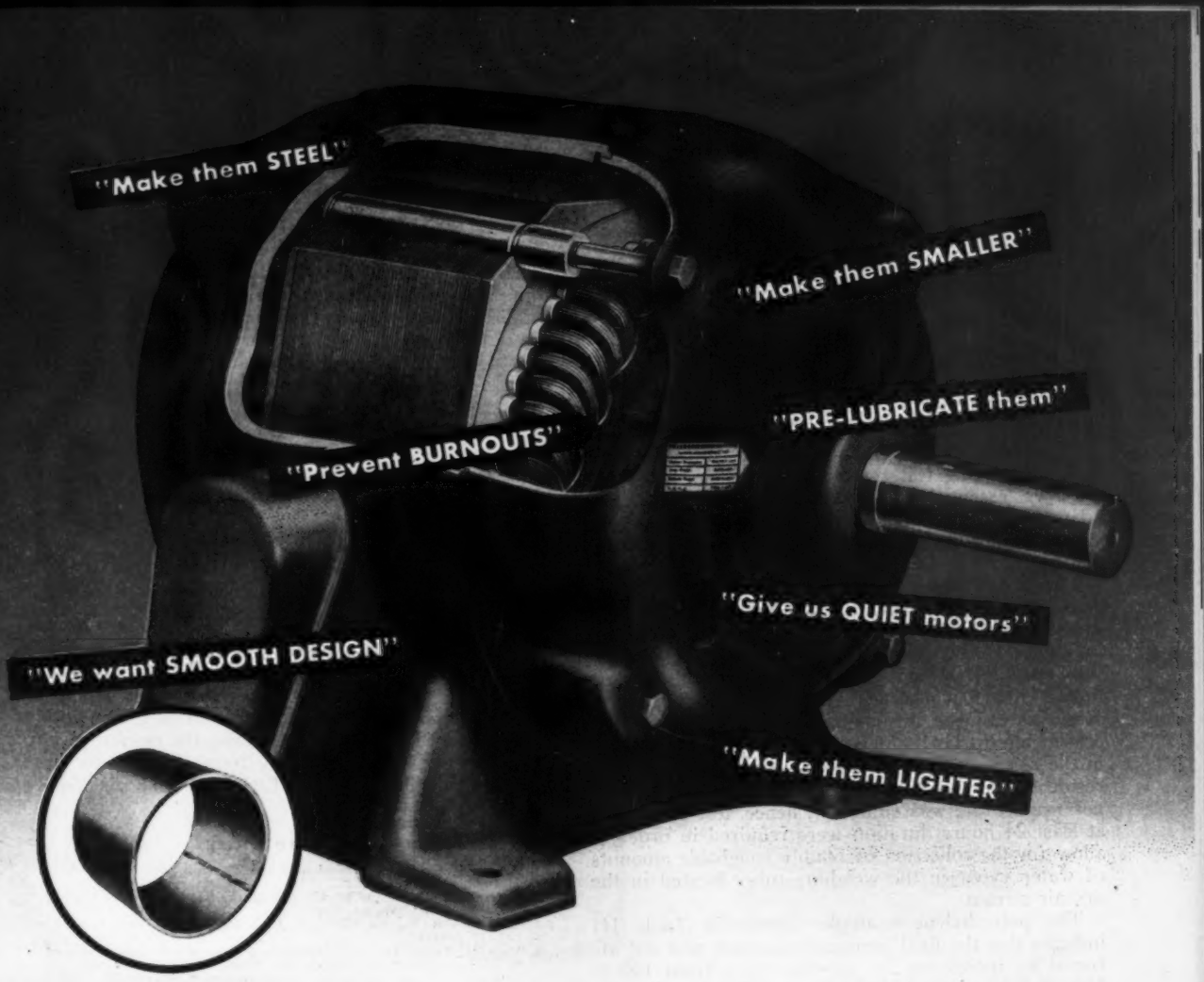


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TABLE III.—WATER VAPOR PERMEABILITY OF PLIOFILM AND POLYETHYLENE AT 0° F. (100% R.H. VS. 0% R.H.) DETERMINED BY FLOW METHOD

| Test Sample No. | Sheet Material | Thickness, inches | Test Area, sq. cm. | Air Flow * Rates, cc./min. | Rate of Gain in Dry Air, g./hr. | W.V.P., g./sq. m./24 hr. |
|---|---|---|---|---|---|---|
| 14 | FF grade Pliofilm | 0.0010 | 2283 | 100 | 0.0017 | 0.18 |
| 15 | FF grade Pliofilm | 0.0010 | 1141 | 100 | 0.00085 | 0.18 |
| 16 | Polyethylene | 0.0015 | 2283 | 100 | 0.00011 | 0.010 |
| 16 | Polyethylene | 0.0015 | 2283 | 500 | 0.00011 | 0.010 |

* Dry air at 70° F.

permeability obtained by the flow method and the cup method described in TAPPI standard method T464 m-45, employing test conditions of 100°F. and 90% R.H. vs. essentially 0% R.H. in each method. The adaptation of the flow methods for determining water vapor permeabilities at 0°F. therefore appears valid and justified on the basis of these results.

The water vapor permeabilities of Pliofilm (FF grade) and polyethylene as determined by the flow method at 0°F. (100% R.H. vs. 0% R.H.) are given in Table III. In the case of Pliofilm, the permeation rate was high enough to permit test periods of less than 24 hours, if desired, even when the effective test area was reduced by one-half or from 2283 square centimeters to 1141 square centimeters. No difference in the resultant permeability value was apparent as a result of this change. With polyethylene film, the permeation rate was quite low, hence, test periods of at least 24 hours duration were required in order to allow for the collection of readily weighable amounts of water vapor in the weighing tubes located in the dry air stream.

The polyethylene examples shown in Table III indicate that the final permeability result was not affected by increasing the air flow rates from 100 to 500 cc. per minute. This is an indication that the flow rate of 100 cc. per minute was adequate to avoid stagnation of the air and maintain the desired vapor pressure difference across the test samples. The latter was further indicated by calculations based on the amount of water vapor contained in the effluent moist and dry air streams.

The rates of gain of water vapor in the dry air side, during the tests on Pliofilm and polyethylene, are shown in Fig. 3. The blank values are shown in the broken line portion of the curves. The blank for Pliofilm, after equilibrium is reached, amounts to about 2% of the actual permeability value and can be disregarded. With polyethylene, however, the blank amounts to about 12% and is taken into consideration in calculating the actual water vapor permeability.

The curves in Fig. 3, also indicate that, with Pliofilm and polyethylene, a constant rate of gain is established in a short time after the beginning of the test. However, experience with other sheets, such as wax laminated papers, indicates that long periods of time may be required before equilibrium conditions are established.

The present investigation has been confined largely to a study of the factors involved in the use of the method. This work is being extended to determine the water vapor permeabilities of most commercially used frozen food wrappers. The method is suitable for determining the permeability of such wrappers down to about 0.01 grams per square meter per 24 hours (0°F., dry vs. saturated conditions).


### Acknowledgments

The author wishes to express his appreciation to Donald W. Davis and George J. Brabender for their helpful suggestions and assistance in the development of this method. A further expression of gratitude is due George Brabender for reporting the results, given in this paper, of permeability tests obtained by the cup methods described in TAPPI Standards T448 m-46 and T464 m-45.


### Literature Cited


1. Barrer, Richard M., "Diffusion in and Through Solids," New York, Macmillan Company, 1941.
2. Doty, Paul M., Aiken, W. H., and Mark, H., *Ind. Eng. Chem.* 21, No. 8: 788-791 (August, 1946).
3. Lishmund, R. E., and Siddle, F. J., *J. Oil Colour Chem. Assoc.* 24: 122-137 (1941).
4. York, J. Louis, Office of Production Research and Development, War Production Board, Project No. M-544 (February 1, 1945).
5. Institute of Paper Chemistry. Instrumentation Studies LI. *Paper Trade J.* 121, No. 13: 68, 74, 78, 80, 86, 91 (September 27, 1945); *Paper Trade J.* 121, No. 16: 32-42 (October 18, 1945).
6. Tressler, Donald K., and Evers, Clifford E., *Paper Trade J.* 101, No. 10: 33-35 (September 5, 1935).
7. DuBois, Clarence W., and Tressler, Donald K., *Paper Trade J.* 109, No. 20: 15-18 (November 16, 1939).
8. Rabak, William, *Paper Trade J.* 111, No. 9: 80-82 (August 29, 1940).
9. TAPPI Standard T448 m-46 (May, 1946).
10. TAPPI Standard T464 m-45 (September, 1945).
11. Packaging Institute. Standard Test Method 1. *Modern Packaging* 19, No. 41: 140-142, 172 (July, 1946).
12. Schumacher, Earle E., and Ferguson, Lawrence, *J. Am. Chem. Society* 49: 427-428 (February, 1927).
13. Edwards, R. S., *J. International Society Leather Trades' Chemists* 16: 439-449 (1932).
14. Davis, Donald W., *Paper Trade J.* 123, No. 9: 33-40 (August 29, 1946).


# The Gravimetric (Weighed-Cell) Method of Determining Water Vapor Permeability*


By F. T. Carson[1]



### Abstract

*Most measurements of water vapor permeability in the last 20 or 30 years have been made by the gravimetric (weighed-cell) method. The evolution of this method is outlined, including a discussion of such topics as the following: method of sealing, defining the area, ventilation of surfaces of specimen, condensation of moisture, desiccant in cell, vapor-pressure and moisture gradients, steady state of transmission, use of counterpoise, accelerating the test, and agreement among common methods.*

*The better techniques require a wax seal completely enveloping the edges of the specimen and defining a predetermined test area by casting the wax around a*



* Presented at the Annual Meeting of the Technical Association of the Pulp & Paper Industry, Hotel Commodore, New York, N. Y., Feb. 24-27, 1947.



[1] Technologist (Paper) National Bureau of Standards, Washington, D. C.

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**HIGHLIGHTS:**

California, in 1857 had the first paper mill in the United States west of the Mississippi River. Its Fourdrinier machine, built in South Windham, Connecticut, made the perilous voyage to Panama on a vessel; there it was transported on skids across the Isthmus and reshipped to Taylorsville, California.

Many years passed before papermaking was extensively carried on in this State, which now ranks 14th, with an annual output of over 392,000 tons.

In the fourteen paper mills, cylinder machines to the number of 18 predominate. There are also four Fourdriniers, one Yankee machine, and two wet machines. There is but one pulp mill, which is listed as having a capacity of five tons per day of soda pulp. Building papers such as saturating felt, sheathing, etc., and miscellaneous paperboards are the leading products. Tissues for fruit wraps constitute appropriately, another item.

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*template; a desiccant or a source of water vapor within the permeability cell close to the specimen; and a well ventilated room, cabinet, or oven at constant temperature and humidity in which to expose the cell. Limiting the higher humidity to 90 to 95% avoids condensation and other irregularities at very high humidities. Weighing the cell in the atmosphere in which it is exposed is desirable.*

*Data from published reports indicate that modifications of the weighed-cell method, differing in details that may appear unimportant, often give results that differ by several hundred per cent, but that, when a well chosen procedure is rigidly adhered to, the agreement should be within 25 to 30%.*

In the last 30 years, and for the most part in the last 20 years, a considerable amount of work has been done to evaluate various kinds of membranes and sheet materials as moisture barriers. On the one hand measurements are made on relatively permeable materials used for clothing, such as textiles and leather, to determine how readily they might be expected to dissipate perspiration; and on the other hand many measurements are made on materials designed to resist the passage of moisture, such as electrical insulation, sheathing paper, and packaging materials.

Most of these measurements have been made by means of various forms of the gravimetric method. This method, which is often referred to as the cup method, involves the use of a permeability cell (cup or dish) of such size and shape that it can be readily weighed on an analytical balance. The thing that characterizes the method is not merely the use of the weighing technique but the weighing of the whole permeability cell or cup. Weighing an absorbent to evaluate transpired moisture is sometimes used in other permeability methods as well. Briefly stated, the method is exemplified by the early technique of sealing a specimen of the material to be investigated over the mouth of such a permeability cell containing some water, exposing the cell in a dry atmosphere, and weighing it periodically. The rate of passage of moisture through the specimen is thus established in terms of the rate of change in weight of the permeability cell. Many modifications have been made in this primal technique without changing the basic procedure. The water vapor permeability is usually expressed as the rate of change of weight per unit area for a specified vapor-pressure gradient.

The crystallizing dish, an obvious selection by the chemist, has figured heavily as the cell used in most of these measurements. At first some water was put in a crystallizing dish, a piece of the material to be studied was fastened over the mouth of the dish, which was then weighed and put in a desiccator. After a suitable time interval the dish was again weighed and the loss noted. Out of this simple and fairly obvious beginning have come information and frustration, concert and controversy, headway and headaches.

### Sealing Specimen to Cell

One essential element in the test which has received much attention, both early and late, is the manner of attaching the specimen to the cell. Mechanical clamps have been used, as well as mercury seals, seals with petrolatum, and with all kinds of waxes and gums. As moisture barriers became better the edge seal became more important. Not long ago the beeswax-rosin mixture was very popular, until it was shown to be objectionably hygroscopic. At the present time the mixture of paraffin and microscrystalline wax in approximately equal proportions appears to be serving the purpose very well for ordinary temperatures. At low temperatures specially compounded seals that will not be too brittle have been recommended. In special cases the nature of the material may permit the use of a mechanical seal alone, but for general use a wax seal is considered necessary to insure against leakage.

In the case of laminated materials (and most moistureproof wrappers are laminated) an appreciable leakage between laminations and out through the edges has been observed. Hence recent tendency is to completely envelop the edge of the specimen in the wax seal. In the case of the crystallizing dish this has been accomplished by piling on more wax, or by the inverted sealing technique, or by attaching an outer flexible flange to retain the wax. For at least 10 years some form of the waxing groove that permits sealing in the upright position has been used to some extent. In commercial equipment this type of waxing groove is familiar in the General Foods or Southwick form of cell.

### Test Area

Closely associated with the problem of making an impervious edge seal is the matter of exposing a definite area to the moisture to be transmitted. In the early technique of sealing to a crystallizing dish the test area was somewhat indefinite; it depended upon the diameter of the particular dish used and upon the amount and fluidity of the molten wax. For some time past the test area has been pretty well defined in most work by the use of a template, usually made of a thick metal disk with bevelled edge covered with a film of petrolatum to prevent it from sticking to the hardened wax.

### Movement of Air Over Specimen

Early in the investigation of moisture barriers it became apparent that lack of ventilation in the desiccator of the primitive method led to poor agreement and considerable uncertainty in results. The slow diffusion of the transpired water-vapor through large and varying distances to reach the drying agent proved to be inadequate. Hence one of the most important early modifications of the method was to substitute for the conventional desiccator an oven or a conditioned space automatically provided with a moving atmosphere of definite temperature and humidity. The paper technologist rather early took advantage of the air-conditioned room provided for general paper testing in which to expose and weigh the permeability cells. About 1930 the cell containing water was exposed and weighed in a room at about 70° F. and 50 or 65% relative humidity *(1)*.

A related problem that gained early attention was the effect of the dead air space in the permeability cell between the specimen and the source of water vapor. Experiments reported in 1930 *(8)* pointed out that the apparent permeability values of textile materials were determined by the rate of diffusion of water-vapor through a layer of still air, and did not at all reflect differences in permeability of different textile materials. This difficulty has been resolved in two directions in the case of materials of most interest to this group: (1) by decreasing and standardizing the thickness of the air layer; and (2) by the realization that in the case of very excellent moisture barriers the resistance to diffusion in the air layer

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becomes negligible in comparison with the resistance of the moisture barrier itself. But in the case of the intermediate and poorer barriers the best remedy still seems to be in the direction of decreasing the thickness of the air layer. In one technique much used today this thickness has been reduced to the limit by reversing the gradient, putting granular desiccant in the cell in direct contact with the specimen.

### Condensation of Water on Specimen

A difficulty frequently encountered when water has been used in the cell to produce saturated water vapor is the accidental condensation of moisture on the specimen, which may occur as a result of a slight, sudden decrease in the temperature of the specimen. Wetting of the specimen can also result from careless handling. The paper technologist is familiar with the fact that paper, after it has taken up all the moisture it can from saturated water-vapor, will still absorb a large amount of water if the liquid phase comes in direct contact with it, the additional water being held in the numerous pores that are too large to be filled by any mechanism of isothermal condensation from saturated water-vapor. The large amount of water thus absorbed produces swelling, distortion, and dislocation of the supporting structure, with consequent disruption of the barrier layer in many cases. Certain waxed papers, for example, that are excellent moisture barriers under ordinary conditions transmit moisture readily when they become wet on one side.

One means used to prevent condensation of this character is to replace the water in the cell with a saturated solution of some salt that will produce a high vapor pressure that is somewhat short of saturation with respect to water. The recent tendency has been to abandon pure water as the source of the driving pressure, and to produce instead a relative humidity between 90 and 95% on one side or the other of the specimen being tested.

### Desiccant in Cell

The technique has developed very considerably in another direction. The vapor-pressure gradient is reversed by putting a granular desiccant, such as anhydrous magnesium perchlorate or calcium chloride, in the permeability cell and providing a suitable humidity on the outer face of the specimen. This technique has been used for a long time, and it has many obvious advantages in the matter of preparing and handling the permeability cell. The popularity of this technique is reflected in its choice for both of the TAPPI Standards, T 448 (for ordinary conditions) and T 464 (for tropical conditions).

### Vapor-Pressure and Moisture-Content Gradients

It is difficult to discuss the gravimetric method without considering some aspects common to all methods. Of prime importance are the roles of pressure gradients and humidity gradients. In these relations are found the reasons that TAPPI has found it necessary to have two different gravimetric methods for determining water-vapor permeability.

It was long ago noted that the rate of transmission of water-vapor through a given material is not necessarily proportional to the vapor-pressure difference throughout the humidity range *(3, 6, 12)*.

In trying to arrive at some understanding of why the rate of transmission is in some cases not proportional to the vapor-pressure differences it must first be realized that the passage of water-vapor, as such, through moisture barriers is probably only a minor component. The major process seems to involve the movement of condensed moisture (having a density approaching that of the liquid) within the structure.

Present theory seems to recognize two types of such condensation: one due to solution, and proportional to pressure; and one due to adsorption, and not necessarily proportional to the external pressure. In the latter type appears to be the clue to the lack of parallelism between rate of transmission and pressure difference that is shown by various substances that adsorb considerable amounts of water and swell at the same time that they transmit moisture.

The moisture-content isotherms of cellulosic materials that are sigmoid in character and the rate of increase in moisture content mounting rapidly at the higher vapor pressures are familiar. When a substance such as cellophane is placed initially relatively dry, in an air-conditioned room to season, it appears that moisture condenses at the surfaces and moves inward toward the dry interior. It takes some time for the moisture to become uniformly distributed.

The first stage of this process is not unlike what takes place in a water-vapor permeability test. In the latter case, however, moisture is absorbed on only one surface, goes all the way through to the dry side, and, in the nature of the case, never becomes uniformly distributed. A stable moisture-content gradient becomes established, along which the moisture moves from one face of the sheet to the other. The moisture-content gradient (that resulting from adsorption) is presumably not proportional to the vapor-pressure difference, but increases with pressure in a manner similar to the rate of increase shown by the ordinary moisture-content isotherms.

It becomes somewhat more understandable therefore that the rate of transmission of water-vapor through a substance can be expected to be proportional to the vapor-pressure difference if the substance does not adsorb water, or even though it does, if the moisture-content gradient is kept constant while the vapor-pressure difference is varied. This can be done by changing the temperature while the two relative humidity values on the two faces are kept substantially unchanged.

On the other hand, when there is a change in the relative humidity on one or both faces of the barrier, especially on the high-humidity side, which upsets the moisture-content gradient in a manner out of proportion to the change in pressure difference, there appears to be the condition where rate of transmission ceases to be proportional to the vapor-pressure difference.

This statement of the case is oversimplified, but it presents a simple picture that accords with the familiar experience that some materials that are excellent moisture barriers under ordinary conditions will transmit moisture readily when one face is exposed to a very high humidity. The two TAPPI gravimetric methods therefore reflect a realistic outlook, and it appears that there is much to be learned with respect to this problem.

### Steady-State Region

Another problem of general significance that should be mentioned is that of determining when to begin and when to end the reckoning of rate of transmission as reflected in the weighings of the permeability cell. Many years ago it was customary to begin reckoning the time immediately, with the first weighing that could be made. But it was later observed that, in the

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testing of good moisture barriers, a certain length of time must elapse before the rate of transmission becomes constant, and that to have any long-term significance the measurement must be made in the steady-state region. The steady state of moisture transmission through moderately good moisture barriers may be attained in a matter of hours, or at most in 1 or 2 days. But a much longer time may be required for very good moisture barriers.

It is sometimes difficult to tell when the steady state is attained. Data have been published indicating that 2 or 3 weeks, or even longer, are sometimes required *(4)*. Other data indicate that some materials gradually increase in permeability over long periods of time *(6)*, that is they seem to become progressively poorer moisture barriers as the test proceeds. The opposite behavior has also been observed. Some asphalt-laminated papers have been tested that gradually decreased in permeability for several weeks and then became constant, as if some of the passages initially open to moisture were slowly healing under the test conditions. A creped duplex asphalt-laminated paper, which was observed for 2 months with desiccant on the inside and tropical conditions on the outside, decreased in permeability 40% the first month, and during the second month did not change at all.

In order to locate the steady-state region it is usually recommended that the cumulative weight of the cell be plotted against time until a constant slope is attained which covers several periodic weighings. A more direct method is to calculate the permeability for each interval between weighings and observe directly from the data sheet when the rate becomes constant within the limits of experimental error.

### Use of Counterpoise

It is related that the Greek philosopher Archimedes was commissioned by King Hieron of Syracuse to aid him in checking up on the suspected rascality of his goldsmith. In the effort to determine whether this ancient sharper had substituted silver for some of the gold in the royal crown, Archimedes discovered that when a body is immersed in a fluid it is buoyed up and appears to lose weight by an amount equal to the weight of the fluid that it displaces. This ancient physical precept contrives to annoy paper technicians of the present day. When a substance in a closed tube, flask, or other voluminous container is to be weighed on an analytical balance it is customary to place a similar closed container on the other pan of the balance as a counterpoise, so that approximately the same volume of air will be displaced by the load on each pan.

In weighing a permeability cell the interest is not in the true weight of the cell or its contents, but rather in differences in weight. Therefore, there should be no need to be concerned about the use of a counterpoise except that in making a series of weighings the density of the air may change slightly from time to time. In extreme cases this change may result in errors of a few milligrams, which are not negligible when good moisture barriers are being tested.

Some have thought the ideal counterpoise to be a second, empty permeability cell with a duplicate specimen sealed over its mouth. But it has been pointed out that such a counterpoise may change in weight for a long time, as the attached specimen gains or loses moisture at the one free face, since some of the moisture must go through the barrier to the inside, or vice versa according to the conditions. The better the moisture barrier the worse this condition becomes. The resulting error may be greater than if no counterpoise is used. Others have advocated a counterpoise of fixed volume, in which the specimen is replaced by sheet metal. But there again the cure may be worse than the malady, since a fixed volume is counterweight for a volume that varies with change of atmospheric pressure.

When the pros and cons are weighed against each other they appear to strike a pretty good balance without the use of a counterpoise. It is noted that the counterpoise, or tare cell as it is often called, has been dropped from the TAPPI methods. Perhaps the best solution is to leave as little air as possible in the cell, reduce the depth of the cell as much as is consistent with the job to be done, and ignore the counterpoise. This course has also the virtue of simplifying the test.

### Accelerating Test by Increasing Temperature

The test for water vapor permeability is often accelerated by increasing the temperature. At 100° F. for example, which is a condition frequently used, the vapor-pressure difference is about two and a half times greater than its value at 70° F., if other conditions remain the same. When this technique involves exposure in an oven or cabinet at a higher temperature than obtains where the cells are made up and weighed, some difficulties may be introduced. If the cells contain considerable air, the expansion resulting from their transfer from the room to the higher temperature may be enough to break the seal or injure the specimens.

Condensation on the specimen is another evil that may result from conditioning at one temperature and weighing at another. Whenever a cooled specimen is placed in humid, hot air, or when a warm cell containing humid air is cooled, condensation is likely to occur.

In this situation also the normal vapor-pressure

TABLE I.—DATA SHOWING DEGREE OF AGREEMENT OF SOME COMMON GRAVIMETRIC METHODS OF DETERMINING WATER-VAPOR PERMEABILITY

| Material Tested | Permeability Values | | | | Ratios | | |
|---|---|---|---|---|---|---|---|
| | GS g/day, m² | T g/day, m² | GI g/day, m² | I g/day, m² | GS/T | GI/I | GI/GS |
| Metal foil laminated to cellophane | 0.2 | 0.1 | 0.2 | 0.2 | 2.0 | 1.0 | 1.0 |
| Waxed glassine | .7 | .1 | 1.6 | .1 | 7.0 | 16.0 | 2.3 |
| Laminated glassine, 3-ply | 1.5 | .1 | 2.0 | .3 | 15.0 | 6.7 | 1.3 |
| Moistureproofed cellophane | 6.9 | .9 | 5.0 | 2.5 | 7.7 | 2.0 | .7 |
| Pliofilm | 6.7 | .9 | 7.9 | 5.0 | 7.4 | 1.6 | 1.2 |
| Asphalt laminated paper—b | 7.8 | 1.4 | 8.8 | 5.9 | 5.6 | 1.5 | 1.1 |
| Asphalt laminated paper—a | 8.7 | 1.4 | 8.8 | 6.1 | 6.2 | 1.4 | 1.0 |
| Greaseproof laminated to board—b | 8.5 | .2 | 11.0 | 8.4 | 43.0 | 1.3 | 1.3 |
| Greaseproof laminated to board—a | 30.4 | .2 | 26.0 | 40.0 | 152.0 | .7 | .9 |
| Ethyl cellulose | 126.0 | 31.2 | 125.0 | 91.0 | 4.0 | 1.4 | 1.0 |
| Lacquer-coated paper—a | 123.0 | 26.5 | 260.0 | 169.0 | 4.6 | 1.5 | 2.1 |
| Lacquer-coated paper—b | 205.0 | 60.3 | 410.0 | 146.0 | 3.4 | 2.8 | 2.0 |

NOTE: Column headings: GS = General Foods method, at National Bureau of Standards (NBS); T = TAPPI official method T 448 at NBS; GI = General Foods method at Institute of Paper Chemistry (IPC); I = IPC method at IPC. Materials tested as two-sided are designated as a (the side having the infusion, barrier, or coating), and b (the side having only plain paper or board), the side designated being that exposed to the higher humidity.

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gradient is upset when the cell is taken out to be cooled and weighed.

Therefore, for high-temperature tests (tests around 100° F.), various means have been devised of weighing the cells in the same high-temperature atmosphere in which they are to be exposed between weighings. One method is to provide a room at the desired temperature in which a low humidity is maintained, expose in it permeability cells containing a suitable solution to produce a high relative humidity, and make the periodic weighings in this room. When the humidity is low enough it is not particularly uncomfortable to work at 100° F. The Institute of Paper Chemistry has used such a technique satisfactorily *(9)*.

When the permeability cell contains the low humidity, and the outer face of the specimen is exposed to the high humidity, the required tropical conditions in a testing room would be too uncomfortable for an operator to work in the room, and furthermore the analytical balance would soon be corroded and perhaps ruined. For this situation conditioning cabinets have been made which are provided with a balance on the outside, and with means of weighing the cells while they remain in the cabinet. The Institute of Paper Chemistry has described an apparatus of this kind also *(10)*. Another was described recently by Cornwell *(7)*.

It seems appropriate at this point to mention the cabinets which are used at the National Bureau of Standards *(5)*. These cabinets are of the air-jacket type, in which the testing compartment is completely surrounded by an envelope of moving air at constant temperature. In the inner compartment the relative humidity is maintained by a saturated salt solution. The small cabinets have been designed especially for permeability work, although they have been used also for determining moisture-content isotherms. They hold from 40 to 60 of the permeability cells of the type being used. These cells, about the diameter of Brabender's two-sided cells and a quarter of an inch deep, were made by pressing annealed aluminum disks between steel dies, not by spinning. They have an external waxing groove, and hold enough dessicant to absorb 2 or 3 grams of moisture when completely filled. They are hung vertically in the cabinet by hooks to a disk that can be turned to bring any cell underneath the balance arm. A weighing rod extending down into the cabinet from the balance is provided with a coupling device by means of which the selected cell can be hung to the balance arm for weighing. A preheating compartment is provided, and fresh cells can be introduced at any time without altering the conditions within the cabinet and without condensation on the specimens.

### Comparison of Results by Different Modifications of Method

In view of the numerous variables that affect the test and the many modifications that have been made in the gravimetric procedure, it is not unexpected to find that results obtained by the different techniques often do not agree very well.

Many will recall that 3 or 4 years ago TAPPI sponsored a comparison of some current gravimetric methods. Two reports on this work were published, one by Weber *(13)* of the National Bureau of Standards, and the other by Sears, Schlagenhauf, Givens, and Yett *(11)* of the Institute of Paper Chemistry. These two sets of data, when considered together, permit the formation of some idea of the degree of agreement that can be expected in different gravimetric methods.

The first comparison in the accompanying table (Table I) is between the General Foods method and TAPPI method T 448. One test is made at 100° F. with a relative humidity well above 90% on the outer face of the test cell, and the other at 73° F. with a relative humidity of 50% outside of the cell. In both cases a granular desiccant is enclosed in the permeability cell. The ratio of the two vapor-pressure differences is estimated to be between 4.5 and 5. Eight of the twelve permeability ratios (fifth column) lie between 3.4 and 7.7, not far from that which would correspond to vapor-pressure difference alone. The high values, however, are far out of line.

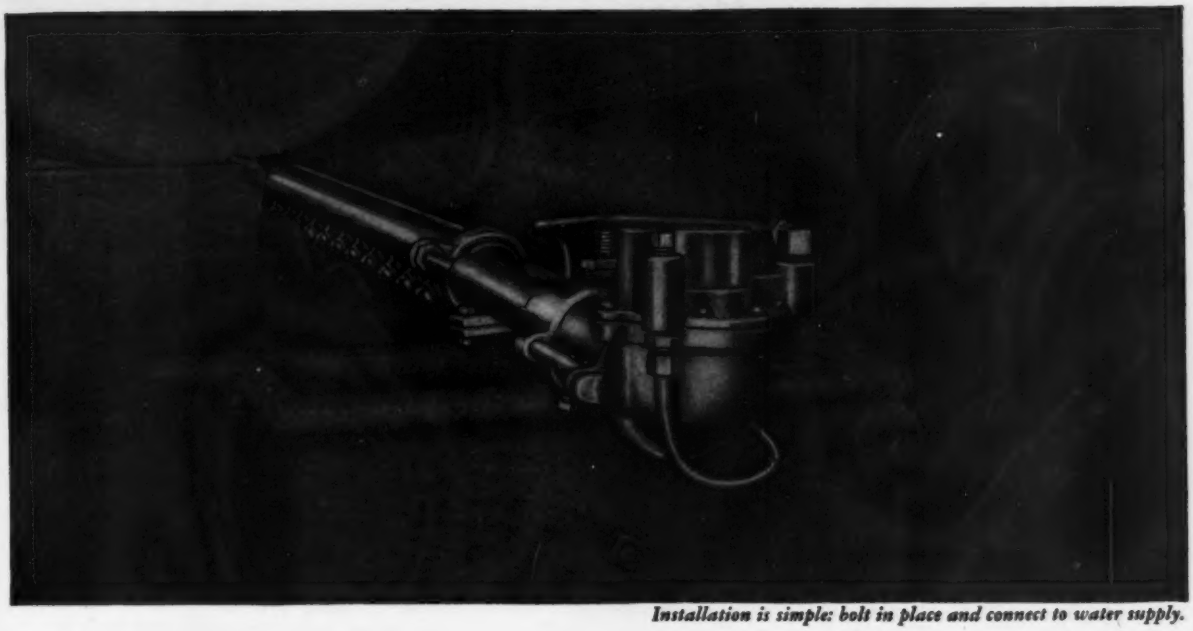
Comparable tests which were made on 24 varieties of asphalt-laminated papers, using Bureau of Standards type of cabinet instead of the General Foods cabinet, and weighing the permeability cells in place, yielded an average ration between 9 and 10, or about twice that corresponding to vapor-pressure difference alone.

The second comparison is betwen the General Foods method and the Institute of Paper Chemistry method. Both tests were made at 100° F. and both have a relative humidity above 90% on one face of the specimen, and dry air on the other. But the General Foods method has probably a little the higher humidity on the high-pressure side and it has a lower humidity on the dry side. The estimated ratio of vapor-pressure differences is about 1.3. Eight of the ratios (sixth column of table) are between 1 and 2, and two others are not far beyond this range. Two materials, the glassine products, however, are rated very differently by the two methods.

When the comparison of the same method (General Foods) in two different laboratories is made better agreement is found throughout, although it is still considerably short of being perfect. The ratio (seventh column) which we expect to be 1, ranges from 0.7 to 1.3, with three exceptions. A study of the reports indicates that for these three exceptions, having a ratio from 2.0 to 2.3 (differences of 100 percent or more), unrepresentative sampling is probably responsible for most of the discrepancy.

In 1939 comparative tests *(2)* by nearly a dozen laboratories, preliminary to the writing of TAPPI method T 448, were reported. In these tests the permeability cells contained a granular desiccant and were exposed and weighed in an atmosphere of 65% relative humidity and at a temperature of 70° F. The various laboratories reported average results differing from the average of all (for a given material) by amounts ranging up to more than 100%, with a mean difference ranging from 15 to 44% on seven kinds of packaging material.

It is still in a period of development and individualism in technique. Although there are certain standards, they allow considerable latitude in detail. Proponents of this or that technique or modification tend to hold fast to their individual preferences. This situation is consistent with growth and development, and will adjust itself in time. If and when a single best method and technique is developed, and all adhere closely to it, it can be reasonably certain that a series of moisture barriers can be correctly classified by any one of various observers with at least as much assurance as obtains in the use of other common paper-testing methods.



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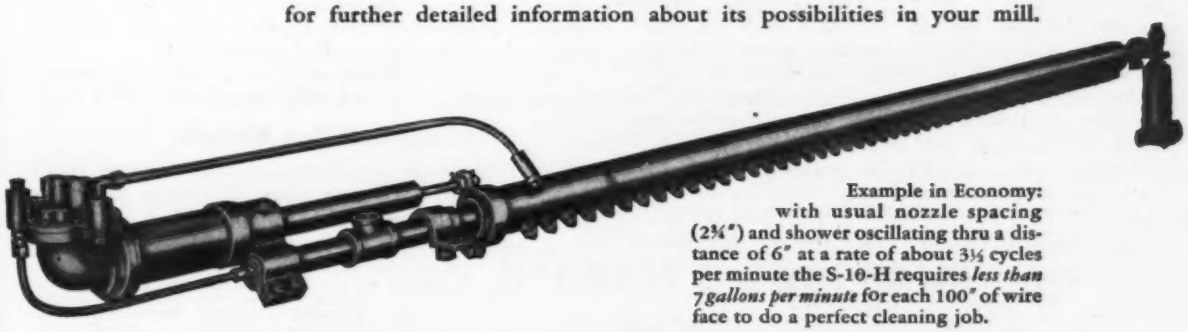

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For a long time the gravimetric, or weighed-cell method, has been found to be a very useful testing and research tool and, although it sometimes seems exasperatingly slow, it will probably continue for some time to come to be the mainstay of those who are called upon to evaluate moisture barriers.

### Literature Cited


1. Abrams and Chilson, *Paper Trade J.* 91, TS 193 (1930).
2. Brabender, *Paper Trade J.* 108, TS 31 (1939).
3. Brabender, Proc. First Food Conference, Inst. Food Tech. 1, 227 (1940).
4. Brabender, *Paper Trade J.* 119, TS 160 (1944).
5. Carson and Worthington, Cir. Nat. Bu. Standards C453 (1946).
6. Charch and Scroggie, *Paper Trade J.* 101, TS 201 (1935).
7. Cornwell, *Paper Trade J.* 120, TS 82 (1945).
8. Gregory, *J. Text. Inst.* 21, T 66 (1930).
9. Inst. Paper Chem., Report No. 30, Part III (1943).
10. Inst. Paper Chem., Report No. 30, Part VI (1944).
11. Sears, Schlagenhauf, Givens, and Yett, *Paper Trade J.* 118, TS 27 (1944).
12. Taylor, Herrmann, and Kemp, *Ind. Eng. Chem.* 28, 1255 (1936).
13. Weber, *Paper Trade J.* 118, TS 24 (1944).


# Transmission of Odor Through Packaging Materials*


By L. W. Elder[1]



### Abstract

*A brief summary of suggested test methods for the determination of odor transfer through packaging materials is given.*


In the distribution of packaged food products through commercial retail channels the problems of odor transfer through packaging materials can arise in one of two ways. Products whose flavor depends in part on volatile aromatic materials can lose sales appeal by evaporation of the volatile flavor if such vapor can escape by diffusion through the package structure. Alternatively, a product can be damaged by contamination with foreign odors such as petroleum products, fish, bag-packed coffee, perfumed soap, and similar commodities which might be stored in the vicinity in warehousing or freight handling. Generally speaking, the problem of flavor loss by evaporation is not a serious one. However, many food products are peculiarly susceptible to contamination by foreign odors. These include such commodities as shortening, butter and other fatty products and delicately flavored products such as tea.

A rather unique problem involving odor transfer arises in the case of packaged prepared cereal products. The most desirable physical properties in such cereals are achieved when the moisture content is held below 7%. It is precisely under these very dry conditions that off odors can accuumulate due to oxidative deterioration of the fractional percentage of fat contained in these cereals. Normally, such odors are not a serious obstacle if the package allows a reasonable amount of free ventilation. However, the specification of a maximum moisture content of 7% definitely prescribes a water vapor barrier for successful merchandising. In this case, the ideal package should have a selective permeability for organic vapors and a high degree of impermeability to water vapor.

"Flavor" by E. C. Crocker *(1)*. Crocker's monograph lists these compounds in chapter 8, classified according to their vapor pressures at 20°C. It is quite remarkable that the vapor pressures of these so-called volatile materials do not exceed 3 mm. and the range extends down as low as 0.001 mm. A few selected examples taken from Crocker's listing are shown in Table I together with their vapor pressures expressed both in millimeters of mercury and as parts per million by volume in saturated air. It is to be noted that although air saturated with vanillin contains only 7 p.p.m. by volume of this compond, a quantity about 1/3000 of the volume of water vapor in air saturated at 20°, nevertheless, vanillin is detectable by odor in concentrations ranging from 1/100,000 to even lower fractions of its concentration in saturated air. The uniqueness of these compounds apparently resides in the sensitivity of the human nose toward their presence rather than extreme volatility in the normal sense of the word. The nature of the problem involved in measuring the transmission of such vapors through packaging materials is shown in Table I by a comparison of their vapor pressures with that of water at 0°F. In both instances the driving force available for bringing about permeation of packaging materials is quite low.

A practical demonstration of the low escaping tendency of a typical aromatic fraction of a food product was obtained some years ago in this laboratory when it was shown that freshly ground coffee can be ventilated with a volume of nitrogen 5,000 times as great as the void space of the coffee itself without significantly lowering the cup quality of the coffee as judged by qualified experts *(2)*.

An excellent treatment of odor as related to chemical structure was published by Moncrieff in 1943 *(3)*.

### Physical Chemistry of Typical Odorous Compounds

A listing of over 200 compounds representative of volative flavors has been published in the monograph

### Suggested Test Methods

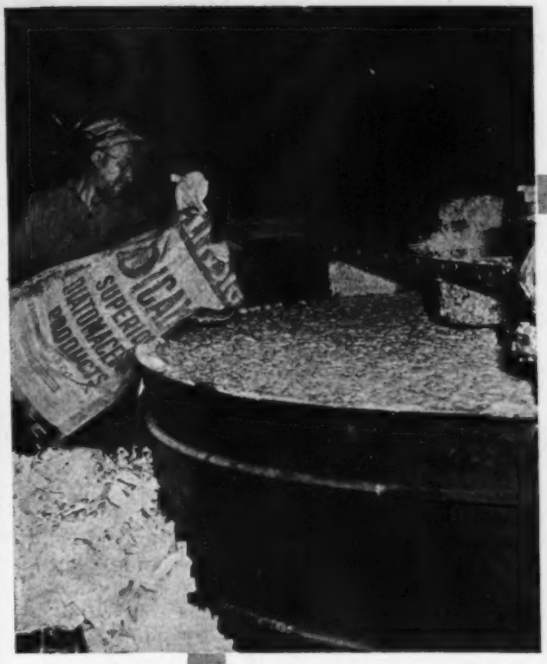
For the purpose of discussion it is assumed that test samples of packaging materials can be mounted in one of the following three ways.

TABLE I.—A FEW SELECTED ODORS AND VOLATILE FLAVORS

| | Vapor Pressure, (20° C.) mm. | Parts Per Million By Volume: In Saturated Air | Parts Per Million By Volume: Detectable by Odor in Air |
|---|---|---|---|
| Vanillin | 0.006 | 7 | $7\times10^{-6}$ to $3\times10^{-5}$ |
| Citral | 0.1 | 130 | .... |
| Benzaldehyde | 0.82 | 1080 | .... |
| d-Limonene | 1.2 | 1600 | .... |
| Butyric acid | 1.0 | 1300 | .... |
| Heptaldehyde | 2.5 | 3300 | .... |
| Allyl mustard oil | 2.54 | 3350 | .... |
| Water (at 20° C. | 17.5 | 23200 | .... |
| Water (at 0° F. | 0.94 | 1240 | .... |

* Presented at the Annual Meeting of the Technical Association of the Pulp & Paper Industry, Hotel Commodore, New York, N. Y., Feb. 24-27, 1947.


[1] Director, Materials and Products Evaluation Laboratory, Central Laboratories, General Foods Corp., Hoboken, N. J.

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A. By supporting a disk over a shallow cup in the manner commonly used for water vapor tests.

B. By mounting a test disk in apparatus designed for registering small pressure changes such as those described by Shuman *(4)* and by Mark and Aiken *(5)*.

C. By mounting multiple sheets of test material in parallel according to the method described by Davis of the Marathon Paper Company *(6)*.

In view of the relatively low vapor pressures involved in saturated vapor, the conventional mecury manometer or McLeod gage used by the references cited would probably be entirely inadequate. Although micro-pressure gages are available for operating in very much lower pressure regions, the practical application to the study of odor permeabilities through cellulosic materials would involve refinements of technique prohibitive in character. The simple cup method could be used to observe loss in weight of the test cell, employing a microbalance. As indicated in Table II, the minimum amount of vapor loss detectable, in this case, would be of the order of 0.01 mg.

The most promising method for mounting the specimen in the author's opinion, is that of the Marathon test procedure. In this case, some means would have to be provided for detecting the organic vapor in the sweep gas. The method could conceivably be based on the use of a cold trap to condense the vapor accumulated after a reasonable time interval, followed by evaporation of the condensate into a limited gas volume, and quantitative estimation of the vapor content by a suitable physical or chemical procedure. Some of the alternative physical methods are indicated in Table II. The sensitivity of the microbalance method can be improved by a factor of about 3 if the vapors are passed over a platinum or other suitable catalyst whereon combustion to carbon dioxide and water vapor could be carried to completion. Absorption of the carbon dioxide and water in the conventional way could be made the basis of a micro-gravimetric method. However, painstaking precautions would be necessary to equilibrate hydrophilic packaging materials so that the water vapor produced by combustion of the organic vapor would not be contaminated by water redistributed from the test sheet.

One of the methods which promises a high degree of sensitivity is that involving measurement of the refractive index of low concentrations of organic vapors in air by means of the gas interferometer. Use of this intrument has been described for measurement of hydrogen permeation of balloon fabrics *(7)*. The instrument is capable of detecting a difference of 2 parts in 100,000,000 in refractive index. Unfortunately refractive indices are not readily available for any of the compounds listed in Table I. A few compounds of similar type for which refractive index data are available are listed in Table III together

TABLE II.—MINIMUM AMOUNTS OF VAPOR DETECTABLE BY VARIOUS MEANS

| | Mg. | cc.* |
|---|---|---|
| 1. Microbalance | | |
| (a) Loss in weight of test cell | 0.01 | 0.0014 |
| (b) Gain in weight of absorbent | 0.01 | 0.0014 |
| (c) $CO_2 + H_2O$ by combustion | 0.003 | 0.0005 |
| 2. Gas interferometer (100 cc. total carrier gas volume) | 0.02 | 0.0028 |
| 3. Spectrophotometer | | |
| (Ultraviolet, Log $E = 4$) | 0.20 | 0.028 |
| (Ultraviolet, Log $E = 5$) | 0.02 | 0.0028 |
| 4. Polarimeter (d-Limonene, $\alpha$ $D = 125$) | 2.00 | 0.2800 |
| 5. Refractometer (for liquids) | | ? |
| 6. Microtitration (or colorimeter) | | ? |
| 7. Micropressure gauge (probably not applicable) | | |

* Assuming vapor density averaging 7 mg./cc.

TABLE III.—VAPORS FOR WHICH REFRACTIVITY IS KNOWN

| | Refractive Index $(N-1)\times10^6$ | Minimum Parts per Million by Volume in Air Detectable by Gas Interferometer | Corresponding Partial Pressure in Air at 1 Atm., mm. |
|---|---|---|---|
| Acetaldehyde | 811 | 37 | 0.028 |
| Chloroform | 1464 | 17 | 0.013 |
| Methylpropionate | 1477 | 16 | 0.012 |
| Benzene | 1820 | 13 | 0.010 |
| Air | 277 | ... | ... |
| Water vapor | 252 | 790 | 0.60 |
| Hydrogen | 139 | 175 | 0.13 |

with an estimate of the minimum concentration in parts per million by volume detectable by the gas interferometer. As indicated by the table, this method appears to have distinct possibilities for materials of suitable high refractive index.

Absorption of vapor from the sweep gas in a suitable solvent, such as alcohol, in a cold trap, opens up the possibility of estimation by ultra-violet spectrophotometry. The sensitivity of this method depends entirely on the extent of ultra-violet absorption by the particular compound selected. This property is expressed by the so-called molecular extinction in the region of peak absorption. Quite a large number of compounds are known for which the logarithms of the extinction approximate 4. A few may show values as high as 5. The corresponding sensitivity in milligrams of organic vapor for these two cases is indicated in Table II. It is also possible to measure the ultra-violet absorption by vapor as such in air. An instrument and method for detecting as little as 1 p.p.m. of toxic gases in air has been described by Klotz and Dole *(8)*.

In the case of optically active compounds such as limonene, absorption of the vapor in alcohol opens up the possibility of estimation by means of a polarimeter. As indicated in Table II, the maximum sensitivity possible by this method is not very high.

Final selection of a test procedure is dependent on a knowledge of what analytical sensitivity is needed, which in turn requires an answer to the question, what degree of permeability is tolerable for a given product? Such questions can be answered only by surveying the well-known vapor barriers, such as glassine and cellophane, by a number of alternative methods and correlating the results with known performance of these packaging materials. Only by means of such tentative correlation will it be possible to show the extent of the vapor leakage, which a laboratory test will be expected to evaluate.

## Literature Cited

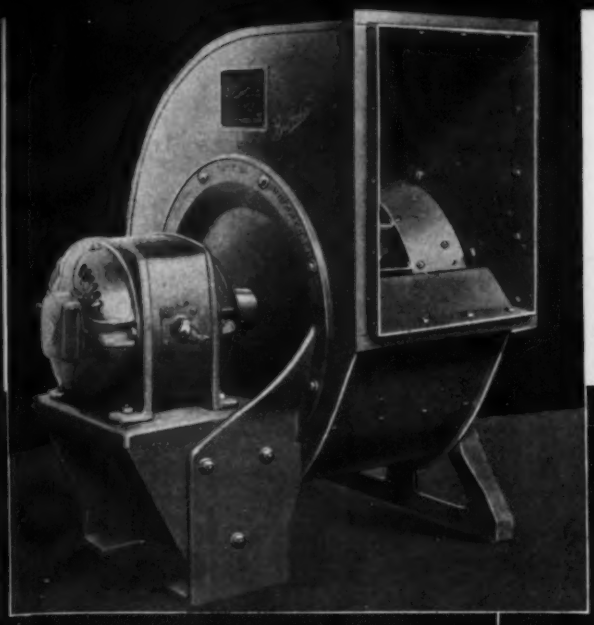

1. Crocker, E. C., Flavor, McGraw-Hill, 1945.
2. Shuman, A. C., and Elder, L. W., *Ind. Eng. Chem.* 35: 778 (1943).
3. Moncrieff, R. W., *Mfg. Chem. and Mfg. Perfumer* 14 (Feb.-Aug., 1943).
4. Shuman, A. C., *Ind. Eng. Chem. Anal. Ed.* 16: 58 (1944).
5. Doty, P. M., Aiken, W. H., and Mark, H., *Ind. Eng. Chem.* 38: 788-791 (1946).
6. Davis, D. W., *Modern Packaging* (May, 1946).
7. Edwards, J. D., National Bureau of Standards Tech. Paper T113 (July 2, 1918).
8. Klotz, J. M., and Dole, M., *Ind. Eng. Chem. Anal. Ed.* 18: 741 (1946).


## New TAPPI Members

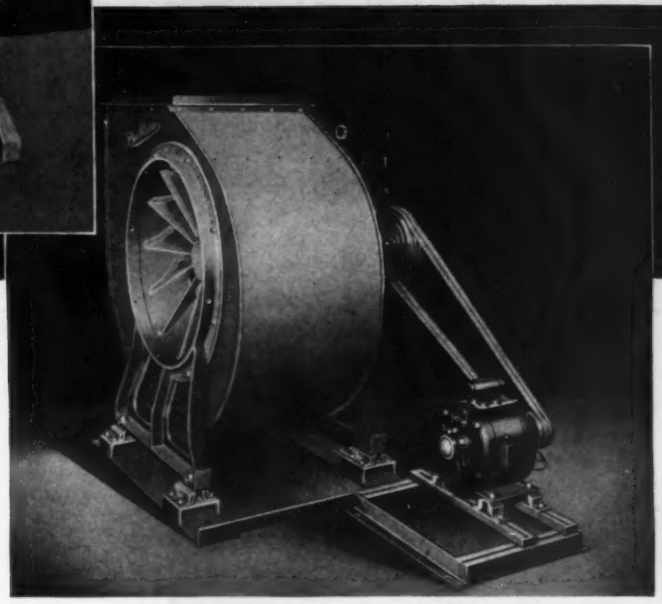
The Executive Committee of the Technical Association of the Pulp and Paper Industry has elected the following to membership:

Donald L. Calkins, Plant Engineer, Wausau Paper Mills Co., Brokaw, Wisconsin. Attended the University of Wisconsin.

Rodger M. Dorland, Director of Research, Abitibi Power & Paper Co., Ltd., Sault St. Marie, Ont., Canada, a 1939 graduate of McGill University with a Ph.D. degree.



# LOW COST AIR MOVERS



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## Lake States TAPPI Changes Meeting Date

The Lake States Section of the Technical Association of the Pulp and Paper Industry will meet on Wednesday, November 12th instead of Tuesday, November 11th which is Armistice Day, at the American Legion Club House, Appleton, Wis., at 6:30 p.m. T. T. Collins of the Thilmany Pulp and Paper Company will speak on the subject "The Use of the Venturi Scrubber on Sulphate Recovery Furnace Stack Gases." During the afternion of the meeting there will be an opportunity to visit the Thilmany mill and see the Venturi scrubber in operation. In addition to the usual reservations for dinner, it is particularly important that the secretary of the local section, G. R. Sears, Box 498, Appleton, Wis., he notified by those expecting to visit the Thilmany mill.

## TAPPI Notes

The annual meeting of the Technical Association of the Pulp and Paper Industry will be held at the Commodore Hotel, New York, N. Y. on February 23-26, 1948. Individuals interested in presenting papers at this meeting should notify R. G. Macdonald, Secretary, 122 East 42nd Street, New York 17, N. Y., before November 20th.

Roger P. Brown, formerly of the Armstrong Cork Company, is now chemist for the Animal Trap Company of America, Lititz, Pa.

Fred B. Schorken, formerly of the Florida Pulp and Paper Company, is now with the Central Paper Company, Muskegon, Mich.

Cyril H. Marsh, research physicist for the Metal Box Company Ltd., is now located at Acton, London, England.

Gerhard H. Klouman has succeeded Robert M. Nelson as official representative of the American Rolling Mill Company, Middletown, Ohio, in the Technical Association.

Harold V. Brady, formerly of Perkins-Goodwin Company, is now with the Ryegate Paper Company, East Ryegate, Vt.

Alfred L. Trumpler, formerly of the Dicalite Company, is now in the sales department of the Niagara Filter Company, Buffalo, N. Y.

Frederick W. Schreiber, formerly of the Personal Products Corporation, is now chief control chemist for the Pepsodent Division, Lever Brothers Company, Chicago, Ill.

M. D. Reuben, formerly of the Paper Drapery Corporation, is now technical director of Erving Paper Mills, Erving, Mass.

O. Walter A. Rodowski, formerly of Cia. Ind. de Atenquique, is now kraft pulp specialist, Sales Dept., Marathon Paper Mills of Canada, Ltd., Marathon, Ont.

Homer F. Ray, formerly of the Scott Paper Company, is now chemical engineer for the National Paper Corporation, Ransom, Pa.

John B. Chandler has succeeded C. P. Lonergan as official representative of the Bristol Company in TAPPI.

William J. Krodel, formerly of the University of Texas, is now chemist for the Celanese Petroleum Research Laboratory, Corpus Christi, Texas.

George D. Knight, formerly of the Institute of Paper Chemistry, is now research chemist for the Grasselli Dept., E. I. du Pont de Nemours, Wilmington, Del.

## Dr. Shallcross Talks To Appleton Kiwanis

APPLETON, Wis.—"The Present Economic Situation" was discussed before the Appleton Kiwanis Club on October 29 by Dr. Ruth Shallcross of the Institute of Paper Chemistry and formerly statistician on War Production Board at Washington, D. C. She assailed government "bungling" in efforts to control prices, and restrictions imposed in an effort to provide more food for Europe.

"If a man like Luckman can close distilleries for 60 days, why not other industries, your own included?" she asked. Closing the distilleries, she said, could help if more than the usual amount of grain is not used afterward.

She declared that people in the United States want prices to remain unchanged, and become about equally "panicky" whether they go up or down. They have the impression that prices can be isolated and controlled and think that "sinister forces, 'robber barons,' are the real causes for high prices and that the government must act as policeman by controlling prices."

As an example of government inefficiency in price control, she pointed to the potato situation, where farmers were encouraged by artificially high prices to plant far more than could be consumed. The government, forced to buy a lot of potatoes it couldn't use, "had no other alternative but to take them, pile them up, pour kerosene on them and burn them in order to keep consumer prices high.

"The consumer paid not only in the artificially high level of prices but lost again in taxes to the government for buying potatoes at those high prices in order to maintain the high price level. It reflects the same type of economic thinking as plowing under crops and the killing of little pigs."

Dr. Shallcross said that the government cannot buy 40 millions tons of wheat in 2 weeks without affecting prices. "No amount of coddling or pretense of saving can make up that loss and we can't fool ourselves on that."

"Our own economy is totally dependent upon our foreign policy. The Marshall plan should carefully be questioned. Can we help Europe without strengthening governments which gain power with our help and which will be bitterly antagonistic toward our system of free enterprise?"

### S. D. Warren Installs Jones-Bertrams Beater

GARDINER, Me.—The S. D. Warren Company recently installed a Jones-Bertrams Patent Beater at their Copsecook mill. The beater is of the very latest design, with fabricated stainless steel tub, glazed white tile bottom, and stainless steel roll bars and bedplates.

LEO N. POCCIA
who has been named chief chemist at the Ogdensburg plant of the Diamond Match Company.

Completely automatic control of beating cycles is provided by a Foxboro control with pneumatic adjustment of roll position. The beater is being used on lightweight rag and sulphite tissue papers. The mill reports that a better closed in sheet is being obtained, and at the same time there has been an appreciable increase in production.

The Jones Bertrams Patent Beater has replaced several older type beaters. It is accomplishing the same work on the stock in about one-third the time previously required and with a considerable saving in h.p. hours per ton. The mill has also installed a new tile stuff chest equipped with a Jones cartridge-type propellor agitating unit.

### Brotherhood to Erect New Headquarters

ALBANY, N. Y.—Construction of new headquarters building for the International Brotherhood of Papermakers, AFL, at Wolfert Ave. and N. Pearl, Menands, at a cost of about $100,000 has been projected by the International Papermakers Realty Corporation.

The Brotherhood, which has a membership of 56,000 in the United States and Canada, has had its headquarters in Albany since 1911 at 30 Sheridan Ave., the Argus Building. The new building, expected to be ready for occupancy Apr. 1 next year, will house a staff of about 50 persons, including executive offices, legal departments and the Papermakers Journal.

J. J. Smith Contracting Company of Albany will erect the building, which has been planned by H. O. Fullerton, Albany architect. Wilson Sullivan Company acquired the plot of land.

## Hoosier Situation Shows Improvement

INDIANAPOLIS — All lines of paper last week seemed to be moving well, with some lines showing increase. In spite of the supply situation many of the jobbers have been able to build up inventories that are heavier than they were a year ago and the same situation promises to prevail at least to the first of the year in spite of the approaching holiday season.

Due to exceptionally fine weather during the fall, demand for building paper and roofing has increased and the fall season is far ahead of last year. Jobbers have fair supplies, but in some instances various grades have been scarce. When severe weather comes, the jobbers will make every effort to build up their stocks against what promises to be a fine spring season.

Newsprint here continued scarce and high. Papers, in spite of the print situation, show increases in advertising lineage. The increase for the first nine months this year for the three major papers was 5,868,728 lines more than the same period a year ago. There has been some talk that the papers will make another increase in circulation charges, but publishers would make no comment. Some time ago rises were made.

Supplies of most tissues continued very short. Toilet tissues were particularly scarce. With the heavy holiday demand coming up a severe shortage is expected during the next month or six weeks. Local jobbers express the belief that no easement in supplies will be noticed for some months.

Box factories continued operations virtually to the extent of their raw material supplies. Advance orders for holiday business have been heavy. The labor situation has not improved.

Waste paper collections were somewhat heavier last week and mills have showed less disposition to buy. Prices were somewhat easier. Better grade rags were in good demand and prices continued firm.

### Ohio Boxboard Elects Thomas Vice-President of Production

RITTMAN, Ohio—S. M. Thomas was elected vice-president, in charge of production, of the Ohio Boxboard Company at the board of directors meeting October 28. Mr. Thomas came to the Ohio Boxboard Company August 15, 1946, to take charge of the mill rehabilitation program then being started. He was appointed production manager November 15, 1946, and has served in that capacity to the present.

For six years previous to joining the Ohio Boxboard Company, Mr. Thomas was vice-president and plant manager of the American Coating Mills at Elkhart, Indiana. From 1928 to 1940 he was the eastern plant manager for the Container Corporation of America in Philadelphia.

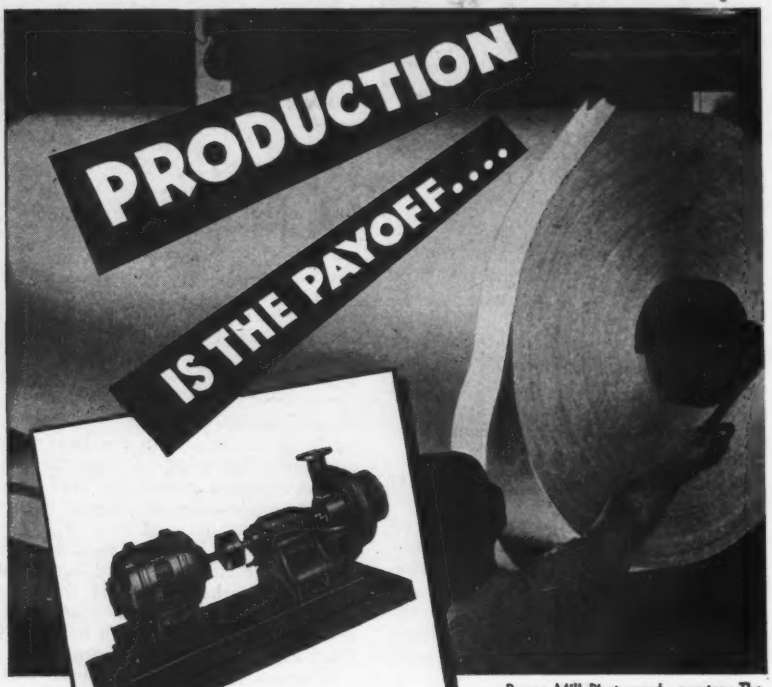
## Twin Cities Labor Joins Safety Promotion

MENASHA, Wis. — The Twin City Trades and Labor Council has affiliated itself with the Twin City Safety Council in promoting all aspects of safety in Neenah and Menasha. The program has been broadened to include safety in schools, in the home and on the highway, in addition to industrial safety.

The safety council has asked all organizations in the two cities to cooperate, and 18 locals of the Trades and Labor Council were represented at a meeting which approved the cooperation proposal.

The Trades and Labor Council also discussed the possible building of a Labor temple and raising dues to increase the building fund. Movies for educational programs at union meetings also were discussed.

The speaker was Emil Noreen, international representative of the International Brotherhood of Papermakers (AFL), who discussed the progress of organization in the area and stressed the importance of member attendance at meetings.



PRODUCTION
IS THE PAYOFF....
Warren Liquor Pump, Type "L"
Paper Mill Photograph, courtesy The Champion Paper and Fibre Company

Production is the payoff—as every superintendent knows . . . quality and quantity production . . . and that's where Warren Pumps really pay off.

Warren offers a specially engineered pump for practically every application . . . for handling pulp stocks, liquors in sulphite, soda and Kraft mills, water for mill supply, showers, white water, wash-down, etc., for boiler feed and all power plant requirements.

For Greater Dependability . . . Longer Life . . . Lower Maintenance . . . all important factors in PRODUCTION . . . the PAYOFF . . . Specify:

**WARREN PUMPS**

WARREN STEAM PUMP COMPANY, INC., WARREN, MASS.


## McMaster Is Made Vancouver Port Master

VANCOUVER, B. C. — Alfred E. McMaster, former paper executive, has been appointed manager of the Port of Vancouver, according to announcement by Hon. Lionel Chevrier, Minister of Transport. Mr. McMaster will succeed K. J. Burns when the latter retires at the end of this year.

Mr. McMaster, 62, came to Prince Rupert in August, 1908, as passenger and freight agent for the Grand Trunk Pacific.

He remained there until 1913 as general agent also for Grand Trunk Pacific Steamships. In 1917 he was in war work for the Canadian Manufacturers' Association in Toronto and Detroit, and came back after the First Great War to join the Port Arthur Shipbuilding Co., owned by James Whalen and associates.

For them he moved to Vancouver and was there until 1921, operating the Whalen sulphite pulp plant at Woodfibre and other plants at Swanson Bay and Port Alice. In 1921 he joined the Powell River Company, and in 1926 succeeded Norman Lang as manager of that company.

He initiated the Lois River power development and during his term at Powell River, newsprint output increased from 65,000 to 220,000 tons per year. He resigned from Powell River Company in 1936 to become managing director of the Nootka Pulp Company, where his work was finished in 1938. He spent the next year or two with the late A. J. T. Taylor, exploring pulp enterprise possibilities on Vancouver Island and had plans worked out for a plant at Duncan Bay when the war intervened.

He acted as government administrator for seizure and sale of Japanese fishing vessels in 1942 and was the executive under Mr. Justice Smith in the disposal of other Japanese properties when these people were expelled from the B. C. coast.

Since May, 1943, he has lived in Ottawa, being successfully assistant to the financial advisor of the federal government, associate wood fuel advisor, coordinator of controls and liaison officer of the department of labor, and finally vice-president of War Assets Corporation.

## International Paper Products Opens in New Orleans

NEW YORK — International Paper Products Division of International Paper Company has opened a branch sales office in New Orleans, with H. Currie district sales manager, at 502 Hibernia Bank Building. Mr. Currie was appointed district sales manager in June and recently moved into his new office.

International Paper Products Division sells the heavy-duty multi-wall kraft paper bags made by subsidiaries of International Paper Company.

# stable

## WAX EMULSIONS

IF EASE of handling and trouble-free performance are what you're seeking in surface applications of wax emulsions, the answer is Paracol* series 400 or 600. Used in the size press or calender stack water box, they remain as stable dispersions, even at a pH as low as 3.5.

For high-quality, low-cost wax emulsions, specify PARACOLS, another group of products in the Hercules diversified line of fine papermaking chemicals.

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# EQUIPMENT AND SUPPLY NEWS

## A-C Organizes Fifth Sales District

MILWAUKEE, Wis.—Organization of a fifth region effective November 1 for the field organization of the Allis-Chalmers general machinery division under Arch J. Cooper, New York district office manager, has been announced by J. L. Singleton, vice-president and director of sales. Formation of the first four regions to be established under the company's long-range sales plan was revealed earlier this year.

The new area, designated as the Empire region, will embrace territory now covered by New York, Buffalo, Rochester, Syracuse and Newark offices. The Rochester and Syracuse offices automatically assume district office status under the regional plan.

Cooper, who has been associated with Allis-Chalmers since 1909, continues as New York district office manager in addition to regional manager. Vernon L. Spinney, formerly New York petroleum sales representative, has been appointed assistant district office manager.

Cooper, who has been manager of the New York district office since 1945, is a graduate of the Sydney (Australia) Technical College. Prior to becoming associated with the company's New York office he was connected with Allis-Chalmers' Boston office. He has long been active in the affairs of the American Institute of Electrical Engineers and the Montclair Society of Engineers.

Like Cooper, Spinney holds an electrical engineering degree and entered the employ of Allis-Chalmers via its graduate training course. A graduate of Pratt Institute, Spinney joined the company in 1930 immediately after completing college. He is also a member of the American Society of Electrical Engineers as well as the Society of Naval Architects and Marine Engineers.

William J. Devers has been named Newark district office manager, while Ned W. Landis becomes a district manager. H. E. Weiss and Robert G. Burns continue as district manager of the Buffalo office and as special representative of the Rochester office, respectively.

### Bagley & Sewall Grants Five-Cent Further Raise

WATERTOWN, N. Y. — Five hundred employes of the Bagley & Sewall Company have been granted a five-cent an hour general wage increase, retroactive to October 13, by Abe Cooper, president of the company. Agreement for the wage increase was made by Harry Marley, plant official, in conference with John E. Wood, district representative for the International Association of Machinists, who represented the union employes.

Besides the five-cent an hour general wage boost, employes were also granted six paid holidays — New Year's Day, Decoration Day, Fourth of July, Labor Day, Thanksgiving and Christmas.

The base pay, including the increase, now ranges from 80 cents to $1.41 per hour, depending upon classification of work.

The latest increase at the Bagley plant boosts to 15½ cents per hour raises which have been secured by workers at the company since February 3. The salary increases were granted primarily to compensate for increased cost of living.

### Bailey Meter Develops New Boiler Control Method

Bailey Meter Company, designer and manufacturer of power and process control equipment, has developed a method of controlling combustion in hog fuel-fired boilers by the brilliancy of the flame, furnace wall or fuel bed.

Because hog fuel comes in many different forms, it differs in size, Btu content, moisture content, volatility, ignition temperature and burnability, making its combustion difficult to control.

The new system of control utilizes a standard arrangement: forced draft is controlled from steam pressure, induced draft from furnace draft, and fuel feed from steam flow. The fuel feed however is readjusted by brilliancy instead of by Steam Flow-Air Flow ratio, the brilliancy being measured by a photo-voltaic cell connected to a Bailey Pyrotron Pyrometer.

In this new type of control a steam flow-meter measuring boiler output proportions fuel feed to steam flow. This type of control has been installed on a hog fuel-fired boiler at a large Pacific Northwest lumber mill and has proven to be very successful in this type of firing.

Complete information available on request to Bailey Meter Company, 1050 Ivanhoe Road, Cleveland 10, Ohio.

### Stocker Names McBride To Pittsburgh Sales

NETCONG, N. J. — Edward McBride has been appointed manager of the Pittsburgh office of Stocker Manufacturing Company. Mr. McBride is a graduate of the University of Pittsburgh, class of 1934. He was connected with the Kress Box of Pittsburgh until 1943, when he joined the Navy. After the war he returned to Kress taking up his duties in the sales department.

## Divisions Setup For Welding Equipment

SCHENECTADY, N. Y. — Announcement of the Welding Equipment Divisions as one of the new integrated operating units within General Electric's Apparatus Department was made this week by R. C. Muir, vice-president and general manager of the department.

The naming of the new division is part of the recent establishment of a new "unit form of management to provide for expanded production" within the Apparatus Department, oldest and largest of the G-E operating departments.

All of the Department's activities in the electric welding equipment field are consolidated in the new Welding Equipment Divisions, Mr. Muir said. The management of the unit will be directed by a Welding Equipment Committee headed by A. F. Vinson, assistant production manager of the Apparatus Department. Other members of the committee are C. I. MacGuffie, manager of sales of the Electric Welding Section, and F. P. Wilson, Jr., staff assistant to the Manager of Engineering.

The committee will be responsible for engineering, manufacture, and sale of G-E welding equipment produced in plants at Holyoke, and Fitchburg, Mass.

### Waste Dealers Expect Busy Western Meeting

ST. LOUIS—All indications point to a very good attendance at the Joint Meeting of the Western Division and the Southwestern Division of the National Association of Waste Material Dealers, Inc., to be held at the Hotel Statler on November 10th, according to a report from Morton A. Friedman and David Charak, co-chairmen of this meeting.

Business sessions of the various commodity divisions and some of the special divisional committees will be held in both the morning and afternoon of Monday. In the evening, a dinner will be served for the members, their guests and their ladies and immediately following the dinner an enjoyable program of entertainment will be presented.

### Haloid Names Piper to Be Works Manager

ROCHESTER, N. Y.—Homer A. Piper has been appointed works manager of the Haloid Company. Mr. Piper, vice-president, has been serving as technical consultant to the president. He has been with Haloid for 23 years.

# NEW LITERATURE

## Edison Company Bulletins Bearing Temperature Monitor

A new 12-page bulletin has been published on the Critical Temperature Monitor. It describes the Monitor as a dependable means of automatic, frequent, and regular temperature checking at selected locations in mechanisms, spaces, or processes which gives an instantaneous identifying indication and alarm when the temperature at any location reaches a predetermined limit, and it enables, at any time, the accurate, centralized reading of existing temperature and observation of temperature change at any remote location. The booklet describes the instrument, its operation and applications, and is illustrated with circuit diagrams and cutaway views.

Copy will be sent to anyone requesting it of Thomas A. Edison, Incorporated, Instrument Division, West Orange, N. J.

## Lewis-Shepard Releases Catalog Number 23

Lewis-Shepard Products, Inc., 290 Walnut Street, Watertown 72, Mass. has released its new 86 page Materials Handling Catalog Number 23.

The catalog contains large-size illustrations of each type of equipment with installations reproduced in duotones, is printed in three colors, and is equipped with special filing-tab cover for quick visual reference. It is a notable addition to the literature of the materials handling field and represents the products of the five divisions of Lewis-Shepard Products, Inc.; Power Truck Division, Power Jacqlift Division, Stacker and Crane Division, Hand-Operated Lift Truck Division, and Floor Truck, Skid Platform and Storage Rack Divisions.

## "CT" Built-In Motors Described by Allis

The Louis Allis Co., Milwaukee 7, Wis. Bulletin 516-D, describes the line of type "CT" Rolled Shell, Shaftless Squirrel Cage Induction Motors for built-in drives with details of Electrical and Mechanical features, mounting, ventilation and applications.

## Dow Company Booklets Describe Ethocel

Two booklets on Ethocel, one entitled "Ethocel Data Handbook" and the other "Recording Lacquers of Ethocel," have been released by The Dow Chemical Company.

The "Ethocel Data Handbook" contains information on the basic properties of Ethocel and suggestions for its use in lacquers, emulsions and hot melts. "Recording Lacquers of Ethocel" is the first of a series of monthly bulletins by the Coatings Technical Service on topics of interest for specialty coating applications.

These new booklets are obtainable in Dow offices throughout the country or by writing to Coatings Section, Plastics Division, The Dow Chemical Company, Midland, Michigan.

## Adsco Flow Meters Bulletin

A new 12-page illustrated Bulletin No. 35-83A on the Adsco Flow Meter of the orifice type for indicating, recording and integrating the flow of steam, gas and air gives details of construction, data on orifice plates, etc. It may be obtained upon request from American District Steam Company, North Tonawanda, New York.


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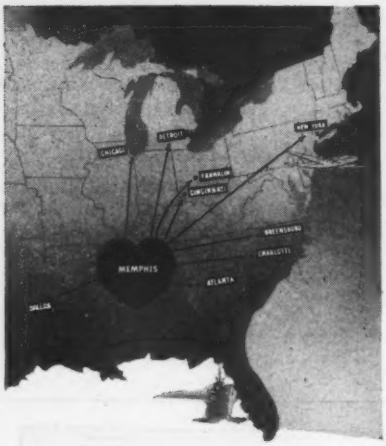


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This special Linter Division allows us to offer you carefully inspected and graded quality linters and assures you of prompt deliveries every time.

For an in-the-mill demonstration of Rayco Linter Cotton, wire or write our nearest sales office.

**THE RAILWAY SUPPLY & MFG. CO. and Affiliates**

*Specialists in Grading, Marketing and Processing Cotton Fibers*

**General Offices: CINCINNATI, OHIO**

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**RAYCO LINTERCOTTON**

## Ocean Falls Workers Get Price Awards

OCEAN FALLS, B. C.—Nineteen employees of Pacific Mills Ltd. were recently presented with $500 in cash awards for suggestions believed by the management to be of vaue in improving production methods or operations at the plant. Presentations were made to the employees by C. W. E. Locke, resident manager, at a labor-management committee banquet in the new company-owned hotel, Martin Inn, at Ocean Falls.

Largest individual winner was Ivor Williams, newsprint machine tender, who received $100. His suggestion was for the installation of instant-acting foot brakes on certain papermaking machines.

Use of these brakes will permit immediate stoppage of the paper rolls if a break or flaw is noticed while the finished paper is being wound at high speeds.

Mr. Williams also received additional awards of $5 each for two minor suggestions.

Millwright Archie Bird was awarded a total of $80 for two suggestions for paper machine changes, and Norman Matheson, paper inspector, received a cheque of $70 for devising a labor saving method of handling heavy rolls of newsprint.

Other winners, who received awards varying from $2.50 to $35, were James R. Cran, John Ninkovich, Cyril Hodson, C. G. Brew, W. J. Calhoun, S. B. Edwards, J. J. McDonald, M. W. Kent, R. L. Skippen, M. Tymchuk, Martin Tworski, C. F. Creech, D. D. Priestman, J. Meunier, S. Hunter and Frank Robertson.

Members of the Ocean Falls fire department also received a group award for a valuable fire prevention suggestion in the pulp and paper plant's sawmill.

Since its inception at Ocean Falls in 1943, the Pacific Mills labor-management committee has studied more than 300 individual suggestions on production and safety matters by plant employees, and has paid out more than $2100 for ideas which proved acceptable. The committee is composed of 12 members, equally divided between union and management groups, and plays a prominent part in such community affairs as sports, entertainment and welfare.

### Ross Paper Machinery Distributes Goulds Pumps

NEWARK, N. J. — The Ross Paper Machinery Corporation has increased its services to the paper industry by taking on a line of new pumps. A large stock of new Goulds pumps is now in their warehouse and available for immediate delivery. In addition to the Goulds pumps, Jack Ross announces that there will be carried in stock pumps manufactured by Deming, Wesco and Robbins & Myers.

A section of the Passaic Street warehouse will be devoted to the new pump line. Service and repair facilities will be available as well as new spare parts for pumps now in use.

H. A. Dunn, president and chief engineer of the New Jersey Pump Company, an affiliate of the Ross Paper Machinery Corporation, is in charge of the pump distributing operations and will devote his forty years' experience in the pump line to better pump engineering in paper mills.

## B. C. Pulp and Paper Opens 50th Building

VANCOUVER, B. C.—Opening of the fiftieth building at the Holberg, B. C., camp of the British Columbia Pulp and Paper Company took place recently. Holberg is the largest logging camp afloat and is at present anchored near the northern tip of Vancouver Island. The camp's 50 buildings include a 66 by 44 foot community hall which serves as gymnasium, dance hall and theatre. There is also a pool hall, store, machine shop, blacksmith shop, carpenter shop, warehouse, firehall, dining hall and cold storage building.

The new building just opened is an improved dining room which has an area of 66 square feet, with a seating capacity for 260. The building has been floated into place in the center of the community, which is a quarter mile in length.

The new dining hall was formerly used as a hospital at a RCAF base at Coal Harbor. British Columbia Pulp & Paper workmen sliced the building in half, placed it on a raft and towed it 20 miles up the coast and assembled it, placing it in position as a unit in this floating camp.

Holberg has a population of 250, including wives and children.

British Columbia Pulp & Paper are cutting at the rate of 4,000,000 board feet a month and expect to log this area for another 10 or 12 years before it is necessary to move the camp.

### Ground is Broken for Continental's New Plant

BUFFALO, N. Y.—John W. Cowper Co. Inc., Buffalo general contractor, has broken ground in the Town of Tonawanda for the new plant of the Continental Can Company Inc. A $1,250,000 contract has been awarded to Cowper by the Can company for the new plant which is expected to employ about 400 workers. It will be situated on a 40-acre site at northwest corner of Brighton Rd. and Colvin Ave.

President Daniel B. Niederlander of the Cowper Company said the plant, a new industry for the Niagara Frontier area, will be ready for occupancy next June. The steel is scheduled for delivery in December. It will be 280 feet by 500 feet. A large part of it will be two stories high and contain a mezzanine floor.

# OBITUARY

### O. T. Thompson

NEENAH, Wis.—O. T. Thompson, 58, died suddenly Saturday, October 25, at Memphis, Tenn., where he had been sent by the Kimberly-Clark Corporation in connection with development and equipment in the firm's plant. Death resulted from heart disease.

Mr. Thompson, who was born June 29, 1889, in Kaukauna, was graduated from the University of Wisconsin as a mechanical engineer. He entered the employ of Kimberly-Clark in 1921, and was assigned to some of the early process development on the then new sanitary products of the company. He became director of absorbent research in 1942 and was made process engineer in 1945, in which capacity he worked on the development of converting equipment.

He was a member of the Neenah Presbyterian Church, the Masons, a charter member of Butte des Morts Golf Club and North Shore Golf Club, and a member of the Century Club and charter member of the Neenah Rotary Club.

His wife, mother, daughter and one sister survive. Funeral services were conducted October 29, and burial was in Oak Hill cemetery at Neenah.

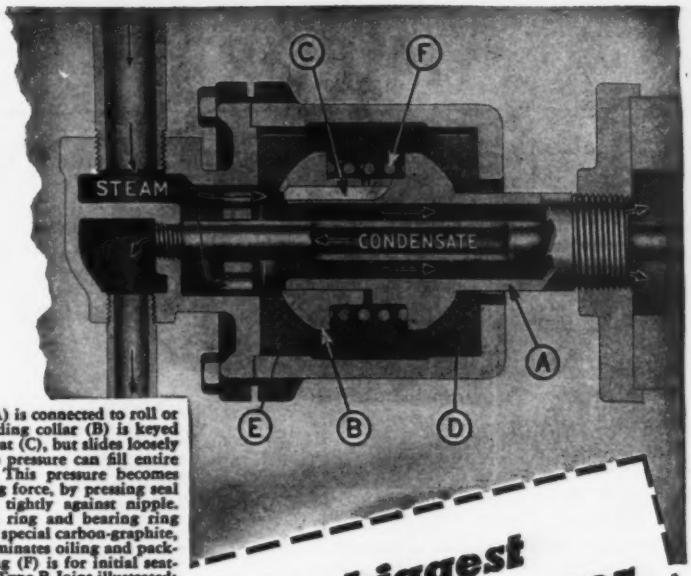
### Clarence D. Bradford

PLYMOUTH, Mass. — Clarence D. Bradford, an executive of the Plymouth Cordage Company, and direct descendant of William Bradford, second governor of the Plymouth Colony, died at his home, 68 Allerston Street, aged 62. He was associated with the Plymouth Cordage Company for 46 years. Mr. Bradford was treasurer of the Mayflower Descendants, the Pilgrim Descendants and the Old Colony Association and participated annually in the Pilgrims' Progress ceremony at Plymouth, taking the part of his distinguished ancestor. He was treasurer of the Plymouth Public Library and clerk of the First Parish, Unitarian.

Living are his wife, Mrs. Helen Clark Bradford; a daughter, Mrs. Horace Gooch, Jr., of Worcester, Mass.; a son, William C. Bradford, of Worcester; a sister, Mrs. Grace Martin, of Plymouth; two brothers, Harry, of Plymouth, and Ruel Bradford, of Brockton; and five grandchildren.

### Raymond Smith

NORTH TONAWANDA, N. Y. — Raymond J. Smith, 56, superintendent of the Soda Department of the International Paper Company plant here for the last 25 years, died recently in a local hospital. He is survived by his wife, two sons, a sister and two brothers.


Nipple (A) is connected to roll or drum. Sliding collar (B) is keyed to nipple at (C), but slides loosely over it so pressure can fill entire housing. This pressure becomes the sealing force, by pressing seal ring (D) tightly against nipple. Both seal ring and bearing ring (E) are of special carbon-graphite, which eliminates oiling and packing. Spring (F) is for initial seating only. Type B Joint illustrated; other types, sizes for all needs.

...it's the biggest little trouble-saver in the mill...

In terms of physical size alone, the Johnson Joint could hardly be called big machinery. But in its ability to save time and trouble, and promote plant efficiency, its stature approaches anything the industry has ever seen.

The Johnson Joint was designed to go after the old stuffing box and steam fit troubles in a business-like way, and it literally knocks the stuffing out of them. There's no packing of any kind. There's no oiling required, ever. There's no adjusting — the higher the pressure, the tighter the seal. There's little to fear from misalignment—with provision for both lateral and angular movement built right in. Note besides how neatly it provides for more efficient syphon drainage, through the same head that admits the steam.

In dollars and cents, what does all this add up to? Well . . . enough at least to pay the cost of switching over to Johnson Joints in just a short while. Enough certainly to make the Johnson Joint too big to overlook.

Write for literature and the name of your nearby Johnson representative.

JOHNSON
Rotary Pressure
JOINTS

THE JOHNSON CORPORATION
828 WOOD STREET
THREE RIVERS, MICHIGAN

# IMPORTS

## NEW YORK IMPORTS

WEEK ENDING NOVEMBER 6, 1947

SUMMARY

| | |
|---|---|
| Newsprint | 13,723 rolls |
| Wallpaper | 6 cs., 16 pcls. |
| Wrapping Paper | 5 cs., 134 rolls, 77 bls. |
| Surface Coated Paper | 4 cs. |
| Photo Paper | 4 cs. |
| Drawing Paper | 3 cs. |
| Paperhangings | 3 cs., 13 bls. |
| Filter Paper | 21 cs. |
| Paper Serviettes | 1 crate |
| Gummed Paper | 63 cs. |
| Miscellaneous Paper | 4 cs., 326 rolls |

### NEWSPRINT

R. A. Olsen, Inc., Donpaco, Donnacona, 374 rolls.

News Syndicate Co., Colabee, Bair Comeau, 6391 rolls.

R. A. Olsen, Inc., A.C.D., Donnacona, 341 rolls.

N. Y. Journal American, Markland, Liverpool, N. S., 690 rolls.

N. Y. Herald Tribune, Markland, Liverpool, N. S., 1757 rolls.

N. Y. World Telegram, Markland, Liverpool, N. S., 423 rolls.

Brooklyn Eagle, Markland, Liverpool, N. S., 700 rolls.

Herald Statesman, Inc., Markland, Liverpool, N. S., 42 rolls.

Washington Post, (Alexandria, Va.), Markland, Liverpool, N. S., 2654 rolls.

Alexandria Gazette, (Alexandria, Va.), Markland, Liverpool, N. S., 27 rolls.

Washington Daily News, (Alexandria, Va.), Markland, Liverpool, N. S., 324 rolls.

### WALLPAPER

Kersten Shipping Co., American Merchant, Havre, 2 cs.

F. Henjes, Paraguay, Copenhagen, 16 pcls.

Balkullen Publishing & Import Co., Gripsholm, Gothenburg, 2 cs.

E. Linde, Inc., Gripsholm, Gothenburg, 1 cs.

Meadows Wye & Co., American Ranger, London, 1 cs.

### WRAPPING PAPER

All Transport, Inc., American Merchant, Havre, 1 cs.

The Borregaard Co., Inc., Gripsholm, Gothenburg, 66 rolls.

Corn Exchange Bank Trust Co., Gripsholm, Gothenburg, 53 bls.

Manufacturers Trust Co., Gripsholm, Gothenburg, 68 rolls, 24 bls.

### SURFACE COATED PAPER

D. C. Andrews & Co., Bowrio, Rio de Janiero, 4 cs.

### PHOTO PAPER

Eastman Kodak Co., Coastal Delegate, Havana, 4 cs.

### DRAWING PAPER

International Expediters, American Ranger, London, 1 cs.

H. Reeve Angel & Co., Inc., American Ranger, London, 2 cs.

### PAPERHANGINGS

W. H. S. Lloyd & Co., American Ranger, London, 3 cs., 13 bls.

### FILTER PAPER

H. Reeve Angel & Co., Inc., American Ranger, London, 21 cs.

### PAPER SERVIETTES

Hutzler Bros., American Importer, Liverpool, 1 crate.

### GUMMED PAPER

B. F. Drakenfeld & Co., American Importer, Liverpool, 63 cs.

### MISCELLANEOUS PAPER

Copeland Shipping Co., Gripsholm, Gothenburg, 2 cs.

Resolute Paper Products Corp., Gripsholm, Gothenburg, 186 rolls.

Manufacturers Trust Co., Gripsholm, Gothenburg, 50 rolls.

National City Bank, Gripsholm, Gothenburg, 27 rolls.

Chemical National Bank, Gripsholm, Gothenburg, 63 rolls.

Tamm & Co., Mormacpine, Stockholm, 2 cs.

### RAGS, BAGGINGS, ETC.

Continental Bank Trust Co., Exchester, Alexandria, 134 bls. old hessian bagging.

(———), Exchester, Alexandria, 109 bls. old hessian bagging.

Manufacturers Trust Co., Exchester, Genoa, 126 bls. old waste bagging.

J. Stein, Bowrio, Buenos Aires, 5 bls. rags.

A. W. Fenton Co., Exporter, Naples, 58 bls. old white cotton rags.

Chase National Bank, American Forwarder, Manchester, 7 bls. wool rags.

J. Eisenberg, American Forwarder, Liverpool, 42 bls. new wool rags.

Price & Pierce, Ltd., Markland, Liverpool, N. S., 216 bls. waste paper.

Continental Bank Trust Co., Blydendyk, Rotterdam, 81 bls. rags.

### GLUESTOCK, ETC.

John Gorvers, Coastal Delegate, Havana, 112 bls. gluestock.

H. Remis, Agwiqueen, Pto Plata, 164 bdls., 171 bags gluestock; 50 bdls. splits.

John Gorvers, Cape Ann, Barranquilla, 194 pkgs. hidecuttings.

Karr Ellis Co., American Forwarder, Liverpool, 666 bdls. hidecuttings.

### CASEIN

Paul A. Dunkel, Bowrio, Buenos Aires, 833 bags.

Hercules Powder Co., Atuel, Buenos Aires, 1667 bags.

### CHINA CLAY

United Clay Mines, Montreal City, Avonmouth, 48 tons, 14 cwt.

### WOODPULP

Phillips Paper Products, Inc., Gripsholm, Gothenburg, 148 rolls sulphite pulp.

Elof Hansson, Inc., Gripsholm, Gothenburg, 1 pkge. sulphite pulp.

Price & Pierce, Ltd., Markland, Liverpool, N. S., 2220 bls. unbleached sulphite pulp.

## BOSTON IMPORTS

(———), Attleboro Victory, Antwerp, 954 bags casein.

## PHILADELPHIA IMPORTS

The Borregaard Co., Inc., Mormacpine, Gothenburg, 90 rolls wrapping paper.

## BALTIMORE IMPORTS

Swedish American Pulp Corp., Mormacpine, Stockholm, 2125 bls. dry perforated bleached sulphite pulp.

Gottesman & Co., Inc., Mormacpine, Gothenburg, 2032 bls. dry sulphate pulp.

## Brazil Increases Its Imports of Paper

WASHINGTON—Brazilian imports of paper and related products for the first four months this year, just reported to this country from official sources, totaled 20,600 tons of newsprint, compared with 18,200 tons for the same months in 1946; 25,100 tons of cellulose for paper manufacture, compared with 24,900 tons last year, and 966 tons of manufactured papers, against 710 tons for the same months a year ago.

In this connection, it was reported that Brazil's new paper mill at Monte Alegre, in Parana, is experiencing some difficulty in reaching the estimated newsprint production first reported for it.

# TRENDS

Office of the PAPER TRADE JOURNAL,
Wednesday, November 5, 1947.

A sensational dispatch from Stockholm that the Swedish government's plans to increase exports of paper cellulose to this country in 1948 by 200,000 tons would result in a price break to our domestic pulp price brought sharp repercussions. Leading importers of Swedish pulp in the city declare that they expect prices to rise by at least the equivalent of the 25-kroner ($7.00) per ton export assessment to be levied by the Swedish government January 31, 1948, for stabilization of the industry. Also there have been unsupported rumors of oceanic freight rises which would add to per-ton prices, but these were since discredited.

During the first seven months of this year, according to Swedish trade figures, their woodpulp exports to the United States have amounted to 347,224 tons, and it generally is agreed that the 200,000 tons mentioned as a probable year's increase would be too small a percentage to affect price in any degree. And a drop in price to our domestic mill price would infer a break in the market which, in view of our present short supply and ever-increasing demand seems incredible. "The objective of the industry," one importer commented, "has always been high-quality paper, and when more pulp is available that will still be our goal."

The urgent need for more dollars probably actuated the Swedish government's suggestion that European cellulose exports be restricted to hard-currency countries; but that Swedish mills will strive against such regulations seems certain. Over a period of many years, it has been the policy of Swedish manufacturers to maintain their established markets on a proportionate basis, and it is considered unlikely that there will be a departure from this principle even under existing circumstances. Also, it is doubted that Sweden can increase her imports to the United States without sacrificing other markets important to her own trade as well as to the program of world reconstruction. It is said that the mills are operating about 50 percent of normal production, that lumber is being used for fuel, that forestry is being controlled, also that labor has been insufficient. It is concluded generally that the European markets will probably get their usual proportion of paper cellulose from Sweden on dollar exchange and that United States mills can count on their proportionate share of the 1948 production, probably at somewhat higher prices.

Rumors continue to come in concerning a rise in Finnish pulp prices for the next quarter.

The only change reported in the steady flow of the paper industry as a whole week this week was the huge supply of waste paper available. Pulp and chemicals continue to plague producers by their short supply.

### Newsprint

No change is indicated to relieve the estimated 5 percent shortage in the United States demand. Neither have the pros and cons of an increase in the Canadian price for 1948 been resolved into a decision; it is still a matter of conjecture. Imports for the week ended October 25 amounted to 6679 rolls.

### Waste Paper

The market has been softened by the well-organized flow of collections, a condition that probably will remain until the weather curtails the flow and the mills absorb the tremendous quantities now available.

Thus far for 1947 collections are 1.8 percent greater than for a like period of 1946, and 16.8 percent greater than in the same period of 1945. Last week's collections were 16 percent ahead of the same week in 1946.

Lower prices are indicated on mixed paper, box board cuttings and old corrugated.

And while collections are high, consumption reached a new high level, October being the highest month since May of 1946. Thus the easier condition of the market is reported to be only temporary.

## Index

The index of general business activity for the week ended October 25 inclined to 145.2 from 143.8 in the preceding week, compared with 138.5 for the corresponding week of 1946. Index of paperboard production declined to 169.8 from 170.4 in the preceding week, compared with 163.5 for the corresponding week of 1946.

Paper production for the week ended October 25 was estimated at 109.7 percent, compared with 108.3 for the preceding week, with 106.8 for the corresponding week of 1946, with 95.8 in 1945, and with 91.3 percent for the corresponding week of 1944.

Paperboard production for the week ended October 25 was 101.0 percent of capacity, compared with 101.0 for the preceding week, with 101.0 for the corresponding week in 1946, with 98.0 in 1945, and with 95.0 percent for the corresponding week of 1944.

## Technical Group Meets At Vancouver

VANCOUVER, B. C.—Members of the Pacific Coast Branch, technical section of the Canadian Pulp and Paper Association, held a one-day autumn session at the Hotel Vancouver recently. Technical papers included one on Power Plant Modernization at the Woodfibre plant of the British Columbia Pulp and Paper Company. This paper was presented by Robert Dekking. Henry Ostrowski, technical supervisor, Pacific Mills Ltd., presented a paper on Recovery and Refining of Knots and Screenings, and R. S. Hatch gave a paper on Magnesia Base Sulphite Pulping and Recovery. A discussion on groundwood problems was also held.

Jack Youden, assistant machine superintendent, Pacific Mills Ltd., said bigger strides had been made during the past two years in technical developments than in any similar period in the history of the industry, but he said demand was so great that there would be no slackening of output for many years in the paper industry. He pointed out that in British Columbia two of the big companies had boosted production considerably by adding around-the-clock shifts on two Sundays per month.

Dr. Norman A. MacKenzie, president of the University of British Columbia, was guest speaker at the dinner meeting concluding the sessions.

## Great Lakes Studies Varied Production

*(Continued from page 68)*

next step in the expansion program.

"An internationally known firm of engineers was commissioned to report on the proposed step, to submit cost estimates and study time factors. Their report affirms the practicability of the proposed development. Parallel with the receipt of this report, official declaration of the new provincial forest policy was made, and, according to the interpretation of the company, its plans conform to this policy.

"Previously, the company was approached by substantial users of pulp in the United States, who were desirous of protecting part of their supply of pulp for a period of years. It is not considered advisable, at this time, to go into details beyond the fact that negotiations are being actively pursued on a basis which will provide the Great Lakes Paper Co. with a guaranteed market for the full output for the proposed plant on satisfactory terms."

Extensive work has been going on at the Fort William plant of Great Lakes Paper Co. for some time. A $1.6 millions program of alterations, replacements and additions in boiler house, wood grinding plant and paper machines was started in late 1946 and was supposed to be completed by the summer of 1948. The engineers on this job are Stadler, Hurter & Co., Montreal.

# PRICES

With the elimination of price controls on paper, pulp, rags and other materials, the quotations given below once more become indicative of trends in an open market. At the moment they can be of little more, for, while some volume business still is being done under contract at the figures given below, fluctuations representing special conditions are too varied and too frequent to permit prices to be given as representing a wholly stabilized market.

## Paper

(Delivered New York)

**Standard News, per ton—**

| | | | |
|---|---|---|---|
| Roll, contract | $87.50 | to | $90.00 |
| Sheets | $109.00 | " | — |

**Kraft—per cwt.—Carload Quantities**
Zone A Deld. 40 lb. base wgt.

| | | | |
|---|---|---|---|
| Superstandard Wrapping | $7.00 | to | — |
| No. 1 Wrapping | 6.50 | " | 6.75 |
| Standard Wrapping | 6.00 | " | 6.25 |
| Standard Bag | 5.75 | " | 6.25 |

**Tissues—Per Ream 24x36 (480) 11 lb. Zone 1.**

| | | | |
|---|---|---|---|
| Wh. No. 1 Frd. | $1.75 | to | $2.00 |
| Wh. No. 1 M. G. | 1.75 | " | 2.00 |
| Wh. No. 1½ | 1.60 | " | — |
| Wh. No. 2 | 1.55 | " | — |
| Kraft Anti-Tar | 1.38½ | " | — |
| Kraft Unbl. | 1.85 | " | — |
| Manila No. 2 | 1.62 | " | — |

**Toilet—Per Case of 100 rolls—1 M Sheets.**

| | | | |
|---|---|---|---|
| Unbleached | $5.50 | to | $6.40 |
| Bleached | 6.50 | " | 7.60 |

**Paper Towels—Per Case of 3750—Zone 1.**

| | |
|---|---|
| Wh. Jr. M'tif'd 9¼x9¼ | $4.85 |
| Br. Sr. M'tif'd 10x12 | 3.45 |
| Br. Jr. M'tif'd 9½x9¾ | 2.95 |
| Br. Jr. Sgl. fold 10x10¾ | 3.10 |

**Manila—per cwt.—C. l. f. a.**

| | | | |
|---|---|---|---|
| No. 1 Jute Tag | $14.50 | to | — |
| Reg. Jute Manila | 13.25 | " | $15.50 |
| No. 1 Manila | 9.75 | " | — |

**Boards, per ton—**

| | | | |
|---|---|---|---|
| News | $92.50 | " | — |
| Chip | 90.00 | " | — |
| Sgl. Mla. Lt Chip* | 102.50 | " | — |
| White Pat. Coated* | 120.00 | " | — |
| Kraft Liners 42 lb. | 100.00 | " | — |
| Binders Boards | 126.00 | " | — |

* Base Prices per 10 tons. Less than 10 tons but over 3 tons, add $2.50; three tons or less, add $5; regular 35-39 basis, add $5; basis 40-49, add $2.50; basis 91-100, add $2.50; basis 101-120, add $5.

The following prices are representative of distributors' resale prices, all deliveries in Zone 1: Rag Content Bonds and Ledgers—

White, Assorted Items
Bonds, per cwt.

| | Carton | 4 C't'n | Ton |
|---|---|---|---|
| 100% Rag Ext. No. 1 | $55.00 | $50.80 | $48.70 |
| 100% Rag | 48.25 | 44.55 | 42.70 |
| 75% Rag | 38.00 | 34.55 | 33.10 |
| 50% Rag | 31.50 | 28.75 | 27.50 |
| 25% Rag | 28.00 | 25.50 | 24.50 |

Ledgers, per cwt.

| | | | |
|---|---|---|---|
| 100% Rag Ext. No. 1 | $54.25 | $50.00 | $48.00 |
| 100% Rag | $47.50 | $43.90 | $42.10 |
| 75% Rag | 37.50 | 34.55 | 33.10 |
| 50% Rag | 32.25 | 29.40 | 28.25 |
| 25% Rag | 28.75 | 26.15 | 25.10 |

Sulphite Bonds and Ledgers—
White, Assorted Items
Bonds, per cwt.

| | | | |
|---|---|---|---|
| No. 1 | $19.25 | $17.50 | $17.00 |
| No. 2 | 18.25 | 16.50 | 16.00 |
| No. 4 | 17.50 | 16.00 | 15.25 |

Ledgers, per cwt.

| | | | |
|---|---|---|---|
| No. 1 | $20.25 | $18.35 | $17.60 |
| No. 2 | 19.25 | 17.50 | 16.80 |
| No. 4 | 18.50 | 16.90 | 16.10 |

**Free Sheet Book Papers—**
White, Cased Paper

| (Per cwt.) | Case | Ton |
|---|---|---|
| No. 1 Glossy Coated | $20.40 | $19.55 |
| No. 2 Glossy Coated | 19.15 | 18.30 |
| No. 3 Glossy Coated | 18.40 | 17.60 |

| (Per cwt.) | Case | Ton |
|---|---|---|
| No. 1 Antique (Watermarked) | $15.90 | $15.15 |
| No. 2 Offset | 14.15 to 17.90 | 13.65 to 17.10 |
| A Grade E. F. | 14.90 | 14.25 |
| A Grade S. & S. C. | 15.40 | 14.65 |
| B Grade E. F. | Nominal | |
| B Grade S. C. | Nominal | |

## Wood Pulp

Domestic mill contract prices delivered with varying freight allowances.

| | Per Short ADT |
|---|---|
| Groundwood | $75.00 to $81.00 |
| Unbleached Sulphite | 115.00 " 117.00 |
| Bleached Sulphite | 121.00 " 130.00 |
| Bleached Soda | 120.00 " — |
| Bleached Sulphate | Nominal |
| Unbleached Sulphate Northern | Nominal |
| Unbleached Sulphate Southern | Nominal |

**Canadian Quotations**

Prices delivered with varying freight allowances unless otherwise specified:

| | Per Short ADT |
|---|---|
| Select Unbleached Kraft (no freight allowance) | 125.00 " — |
| Reg. No. 1 Kraft | 112.50 " 115.00 |
| Unbleached Sulphite | 115.00 " 117.00 |
| Bleached Sulphite | 125.00 " 155.00 |
| Glassine Unbleached Sulphite (no freight allowance) | 112.00 " — |
| Bleached Soda | 120.00 " — |
| Groundwood | 75.00 " 85.00 |
| Sideruns Pulping News | 75.00 " 80.00 |
| Hardwood and Specialty Grades | Nominal |

**Swedish Quotations**
On dock, Atlantic Ports

| | Per Short ADT |
|---|---|
| Bleached Kraft | 170.00 to 195.00 |
| Bleached Sulphite | 175.00 " 185.00 |
| Unbleached Sulphite | 145.000 " 175.00 |
| Unbleached Kraft | 140.00 " 165.00 |

**Finnish Quotations**
On dock, Atlantic Ports

| | Per Short ADT |
|---|---|
| Bleached Sulphite | $175.00 to — |
| Unbleached Sulphite | 145.00 " 150.00 |
| Unbleached Sulphate | 140.00 " — |

## New Domestic Cotton Cuttings

(Prices delivered Mill Plus Dealer's Commission)

| | | |
|---|---|---|
| White Shirt | $11.50 to | $12.00 |
| Light Silesias | 7.50 | |
| Unbleached Muslin | 11.50 " | 12.00 |
| White Back Blue Overalls | 8.50 | |
| Blue Overalls | 7.75 | |
| Unbl. Fancy Shirt | 5.00 " | 5.50 |
| Light Percales | 6.00 " | 6.50 |
| Light Prints | 5.25 " | 5.95 |
| Washables | 4.00 | |
| Bleachable Khaki | 6.00 " | 6.50 |
| Unbleachable Khaki | 5.50 " | 6.00 |
| Cottonades | 5.00 " | 5.50 |

## Old Domestic Cotton Rags

(F.O.B. Shipping Point Plus Dealer's Commission)

| | Per 100 lbs. |
|---|---|
| No. 1 Whites Repacked | $4.50 |
| No. 1 Whites Miscellaneous | 4.25 |
| No. 2 Whites Repacked | 4.00 |
| No. 2 Whites Miscellaneous | 3.50 |
| Blue Overalls | 3.75 |
| Thirds and Blues Repacked | 3.00 |
| Thirds and Blues Miscellaneous | 2.50 |
| No. 1 Roofing Rags | 2.00 |
| No. 2 Roofing Rags | 1.90 |
| No. 3 Jute Bagging | 1.80 |
| No. 4 Brussels and hard back carpets | 1.80 |
| No. 5A Roofing Rags | 1.80 |

## New Foreign Cotton Cuttings

(Prices delivered Mill)

| | Per 100 lbs. | | |
|---|---|---|---|
| New Dark Cuttings | $6.00 | to | — |
| New Mixed Cuttings | 6.50 | " | — |
| Light Sielsias | nominal | | |
| Light Flannelettes | nominal | | |
| New White Cuttings | nominal | | |
| Fancy Shirt Cuttings | nominal | | |
| Light Prints | nominal | | |
| Bleachable Khaki, No. 1 | 7.00 | " | 7.50 |
| Unbl. Khaki, No. 1 | 6.25 | " | 6.75 |

## Old Foreign Rags

(Prices to Mill, f.o.b. dock, N.Y.)

| | Per 100 lbs. | | |
|---|---|---|---|
| No. 1 White Linens | $14.00 | to | 16.00 |
| No. 2 White Linens | 12.00 | " | 13.00 |
| No. 3 White Linens | 8.00 | " | 9.00 |
| No. 4 White Linens | 8.00 | " | 9.00 |
| No. 1 White Cottons | 10.00 | " | 12.00 |
| No. 2 White Cottons | 8.00 | " | 9.00 |
| No. 3 White Cottons | 6.50 | " | 7.00 |
| No. 4 White Cottons | 5.00 | " | 5.50 |
| Extra Light Prints | 7.50 | " | 8.00 |
| No. 1 New Light Prints | 6.25 | " | 6.75 |
| Med. Light Prints | 5.25 | " | 5.75 |
| Dutch Blue Cottons | 5.25 | " | 5.50 |
| Checks and Blues | 4.00 | " | 4.25 |
| Linsey Garments | 3.00 | " | 3.75 |
| Dark Cottons | 2.20 | " | 2.60 |
| Old Shopperies | 2.50 | " | 3.00 |
| New Shopperies | 2.50 | " | 3.00 |

## Bagging

(Prices to Mill, f.o.b. N. Y.)

| | Per 100 lbs. | | |
|---|---|---|---|
| Foreign Gunny, No. 1 | $4.75 | to | 5.00 |
| Domestic Gunny, No. 1 | 4.25 | " | 4.50 |
| Light Wool Tares | 4.50 | " | 4.75 |
| Heavy Wool Tares | 4.75 | " | 5.00 |
| No. 1 Scrap Bagging | 4.75 | " | 5.00 |
| Foreign Manila Rope | 6.00 | " | 6.75 |
| Domestic Manila Rope | 5.75 | " | 6.50 |
| Jute Strings | 4.50 | " | 5.00 |
| No. 1 Sisal Strings | 5.50 | " | 6.00 |
| Mixed Strings | 1.75 | " | 2.50 |
| Mixed Strings, Outthrows | .90 | " | 1.10 |

## Waste Paper

Base Prices to Mills for Average Packings

(Dollars Per Ton)
F.o.b. New York, Baled

| | | | |
|---|---|---|---|
| No. 1 Hard White Envelope Cuts, one cut | 155.00 to | | 165.00 |
| No. 1 Hard White Envelope Cuts | 145.00 " | | 155.00 |
| No. 1 Hard White Shavings, unruled | 145.00 " | | 155.00 |
| No. 1 Hard White Shavings, ruled | 110.00 " | | 130.00 |
| Soft White Shavings, one cut | 145.00 " | | 155.00 |
| No. 1 Soft White Shavings | 135.00 " | | 145.00 |
| Soft White Shavings, Misc. | 125.00 " | | 135.00 |
| No. 1 Fly Leaf Shavings | 45.00 " | | — |
| No. 1 Groundwood Fly Leaf Shavings | 30.00 " | | — |
| No. 1 Heavy Books & Magazines | 27.00 " | | — |
| Mixed Books | 15.00 " | | 20.00 |
| No. 1 White Ledger | 85.00 " | | 90.00 |
| New Manila Envelope Cuttings, one cut | 100.00 " | | 110.00 |
| New Manila Envelope Cuttings | 65.00 " | | 75.00 |
| Extra Manilas | 25.00 " | | 30.00 |
| Mixed Kraft, Env. & Bag Cuttings | 75.00 " | | 85.00 |
| Kraft Envelope Cuttings | 110.00 " | | — |
| Triple Sorted, No. 1 Brown Soft Kraft | 65.00 " | | 75.00 |
| No. 1 Assorted Old Kraft | 55.00 " | | 60.00 |
| New Jute Corrugated Cuttings | 27.00 " | | — |
| Old 100% Kraft Corrugated Containers | 45.00 " | | 50.00 |
| No. 1 News | 13.00 " | | 50.00 |
| No. 1 Mixed Paper | 11.00 " | | 13.00 |
| Box Board Cuttings | 12.00 " | | 14.00 |
| White Blank News | 75.00 " | | 80.00 |
| Overissue News | 18.00 " | | 20.00 |
| Old Corrugated | 25.00 " | | 26.00 |
| Mill Wrappers | 22.00 " | | 35.00 |

## Twines

All Prices Nominal, F.o.b. Mill

(Soft Fiber

| | | | |
|---|---|---|---|
| Coarse Polished—India | .28¼ to | | .29¼ |
| Fine Polished—Fine India | .31¾ " | | .36¼ |
| Unpolished—Paper Makers | .24 " | | .25½ |
| Tube Rope | .24¾ " | | .26¼ |
| Wrapping | .30 " | | .32 |
| Cotton | .55 " | | .70 |

(Hard Fiber

| | | | |
|---|---|---|---|
| Mex. Sisal | .21 " | | .31 |
| Manila (Reprocessed) | .28 " | | .30 |

(American Hemp)

| | | | |
|---|---|---|---|
| Polished Hemp | .36¾ " | | .42 |
| Unpolished | .29¾ " | | .34 |

# PHILADELPHIA

## Domestic Rags (New)

(F.O.B. Eastern Shipping Point)

| | | | |
|---|---|---|---|
| **Shirt Cuttings—** | | | |
| New White No. 1 | .11 | to | .12 |
| New White No. 2 | nominal | | |
| Light Silesias | .07½ | " | .08 |
| Black Silesias, soft | .06½ | " | .07 |
| New Unbleached | .10½ | " | .11¾ |
| Washable Prints | .06½ | " | .07 |
| Washable No. 1 | .05 | " | .05½ |
| Blue Overall | .07½ | " | .08 |
| **Cottons—According to grades—** | | | |
| Washable Shredding | .03½ | " | .04 |
| Fancy Percales | .06¾ | " | .07¾ |
| New Black Soft | nominal | | |
| **Khaki Cuttings—** | | | |
| Unbleachable Cotton Cuttings | .06 | " | .06½ |
| Bleachable Cotton Cuttings | .07 | " | .07½ |
| Men's Corduroy | .05½ | " | .06 |
| Ladies' Corduroy | .05 | " | .05½ |
| Cottonades | .05½ | " | .06 |

## Domestic Rags (Old)

(F.O.B. Eastern Shipping Point)

| | | | |
|---|---|---|---|
| White No. 1—Repacked | 4.50 | to | 5.00 |
| Mixed White | 4.00 | " | 4.25 |
| White No. 2—Repacked | 3.50 | " | 3.75 |
| Thirds and Blues— | | | |
| Miscellaneous | 2.25 | " | 2.50 |
| Repacked | 2.75 | " | 3.00 |
| Roofing Stock— | | | |
| Foreign No. 1 | nominal | | |
| Domestic No. 1 | 1.85 | " | 1.90 |
| Domestic No. 2 | 1.75 | " | 1.80 |
| Roofing Bagging | 1.65 | " | 1.70 |
| Old Manila Rope | 6.50 | " | 6.50 |

## Bagging

(F.O.B. Eastern Shipping Point)

| | | | |
|---|---|---|---|
| Gunny No. 1—Foreign | nominal | | |
| Domestic | 4.50 | to | 5.00 |
| No. 1 Clean Bright—Sisal Strings | .04 | " | .04½ |
| No. 2 Clean Bright—Sisal Strings | .03 | " | .03½ |
| Sisal Jute | .02¾ | " | .03 |
| Scrap— | | | |
| No. 1 | 4.25 | " | 4.75 |
| No. 2 | 1.75 | " | 2.00 |

| | | | |
|---|---|---|---|
| Wool Tares, heavy... | 4.75 | " | 5.00 |
| New Burlap Cuttings | 6.00 | " | 6.50 |

### Old Papers

(F. o. b. Phila.)
Mill Prices, Baled

| | | | |
|---|---|---|---|
| No. 1 Hard White Envelope Cuts, one cut | $100.00 | to | $115.00 |
| No. 1 Hard White Shavings, unruled.. | 100.00 | " | — |
| Soft White Shavings, one cut | 90.00 | " | 95.00 |
| White Blank News.. | 70.00 | " | 75.00 |
| Soft White Shavings. | 80.00 | " | — |
| No. 1 White Ledger. | 80.00 | " | 85.00 |
| Ledger, Colored | 67.00 | " | 70.00 |
| No. 1 Heavy Books & Magazines | 30.00 | " | 32.00 |
| Overissue Magazines.. | nominal | | |
| New Manila Envelope Cuttings | 80.00 | " | — |
| No. 1 Assorted Old Kraft | 60.00 | " | 65.00 |
| No. 1 Mixed Paper.. | 15.50 | " | — |
| Box Board Cuttings.. | 15.00 | " | — |
| Kraft Corrugated Cuttings | 90.00 | " | 100.00 |
| Old Corrugated | 30.00 | " | 35.00 |
| Overissue News | 30.00 | " | — |
| No. 1 News | 18.00 | " | 20.00 |

## BOSTON

### Old Papers

(F. o. b. Boston)
Mill Prices, Baled

| | | | |
|---|---|---|---|
| No. 1 Hard White Shavings, unruled.. | 7.00 | to | 8.00 |
| No. 1 Hard White Shavings, ruled | 7.00 | " | 8.00 |
| Soft White Shavings, Misc. | 6.25 | " | 6.50 |
| No. 1 Fly Leaf Shavings | 1.65 | " | 1.80 |
| No. 2 Fly Leaf Shavings | 2.00 | " | — |
| No. 1 Groundwood Fly Leaf Shavings | 1.25 | " | — |
| No. 2 Groundwood Fly Leaf Shavings | 1.25 | " | 1.50 |
| Mixed Colored Shavings | 2.50 | " | 2.75 |
| New Manila Envelope Cuts, one cut | 5.00 | " | 5.50 |
| Hard White Envelope Cuts, one cut | 3.37½ | " | — |
| Triple Sorted No. 1 Brown Soft Kraft. | 3.50 | " | 3.75 |
| Mixed Kraft Env. & Bag Cuttings | 3.75 | " | 4.00 |
| Kraft Envelope Cuttings | 3.75 | " | 4.00 |
| No. 1 Heavy Books & Magazines | 2.50 | " | 2.60 |
| New Manila Envelope Cuts, one cut | 2.87½ | " | — |
| New Manila Envelope Cuttings | 2.65 | " | — |
| White and Colored Tabulating Cards | 4.25 | " | 4.50 |
| Groundwood Tabulating Cards | 1.35 | " | — |
| White Blank News.. | 1.65 | " | — |
| No. 1 Assorted Old Kraft | 3.50 | " | — |
| No. 1 Mixed Paper.. | — | " | .95 |
| Overissue News | 1.50 | " | 1.75 |
| Box Board Cuttings.. | .72½ | " | — |
| New Corrugated Cuttings, Kraft | 2.25 | " | — |
| Old 100% Kraft Corrugated Containers. | 1.75 | " | — |
| Old Corrugated Containers | 1.50 | " | — |
| Jute Corrugated Cuttings | 1.07½ | " | — |
| Paper Strings | 2.25 | " | 2.50 |

### Bagging

(F. o. b. Boston)

| | | | |
|---|---|---|---|
| Gunny Bagging— | | | |
| Foreign | — | to | 4.75 |
| Domestic | — | " | 4.75 |
| Sisal Rope No. 1 | 6.00 | " | — |
| Sisal Rope No. 2 | 5.50 | " | — |
| Mixed Rope | 5.25 | " | — |
| Mixed Strings | 2.00 | " | 2.50 |
| Transmission Rope— | | | |
| Foreign | (nominal) | | |
| Domestic | 3.00 | " | 3.50 |
| Manila Rope— | | | |
| Foreign | (nominal) | | |
| Domestic | 6.25 | " | — |
| Soft Jute Rope | 5.00 | " | 5.25 |
| Jute Carpet Threads. | 6.00 | " | — |
| Bleachery Burlap | 8.50 | " | 9.00 |
| Scrap Burlap— | | | |
| Foreign | — | " | 4.75 |
| Domestic | — | " | 4.87½ |
| South America | 5.25 | " | — |
| Wool Tares— | | | |
| Foreign | 4.75 | " | — |
| Domestic | 4.75 | " | — |
| Aust. Wool Pouches.. | 5.00 | " | 5.25 |
| New Zealand Wool Pouches | 5.25 | " | 5.50 |
| New Burlap Cuttings | 6.00 | " | 6.50 |
| Heavy Baling Bagging | 5.25 | " | 5.75 |
| Paper Mill Bagging.. | 3.50 | " | 3.75 |
| No. 1 Roofing Bagging | 1.75 | " | — |

### Domestic Rags (New)

(F. o. b. Boston)

| | | | |
|---|---|---|---|
| Shirt Cuttings— | | | |
| New Light Prints. | .08 | to | — |
| Fancy Percales | .07½ | " | .08 |
| New White No. 1.. | .11 | " | .11½ |
| New Light Flannelettes | .08 | " | .08½ |
| Canton Flannels, Bleached | .10 | " | .11 |
| Underwear Cutters, Bleached | .10 | " | .11 |
| Underwear Cutters, Unbleached | .11 | " | .12 |
| Silesias No. 1 | .08 | " | .08½ |
| New Black Silesias.. | .05 | " | — |
| Red Cotton Cuttings. | .05 | " | — |
| Blue Overalls | .08½ | " | .09 |
| Soft Unbleached | .11 | " | .12 |
| Blue Cheviots | .08½ | " | .09 |
| Fancy | .06 | " | — |
| Washable | .06 | " | — |
| Khaki Cuttings | .06½ | " | .07½ |
| Corduroy | .03½ | " | — |
| Khaki Canvas | .06¼ | " | .06½ |
| B. V. D. Cuttings | .10½ | " | .11½ |

### Domestic Rags (Old)

(F. o. b. Boston)

| | | | |
|---|---|---|---|
| White No. 1— | | | |
| Repacked | 3.80 | to | — |
| Miscellaneous | 3.20 | " | — |
| White No. 2— | | | |
| Miscellaneous | 2.65 | " | — |
| Twos and Blues, Repacked | 2.20 | " | — |
| Old Blue Overalls | 2.25 | " | 2.50 |
| Thirds and Blues, Repacked | 2.20 | " | — |
| Miscellaneous | 1.80 | " | — |
| Black Stockings | 3.50 | " | 4.00 |
| Roofing Stock— | | | |
| No. 1 | 2.00 | " | — |
| No. 2 | 1.75 | " | 2.00 |
| No. 3 | 1.35 | " | — |
| No. 4 | 1.35 | " | — |
| No. 5, Quality A.. | 1.35 | " | — |
| Quality B.. | 1.20 | " | — |
| Quality C.. | .95 | " | — |
| Old Manila Rope | 6.00 | " | — |

### Foreign Rags

(F. o. b. Boston)

| | |
|---|---|
| Canvas | (nominal) |
| Dark Cottons | (nominal) |
| Dutch Blues | (nominal) |
| New Checks and Blues | (nominal) |
| Old Fustians | (nominal) |
| Old Linsey Garments | (nominal) |
| New Silesias | (nominal) |

## CHICAGO

### Waste Paper

(F. o. b. Chicago)
Mill Prices, Baled

| | | | |
|---|---|---|---|
| Shavings— | | | |
| No. 1 Hard White Envelope Cuts, one cut | $110.00 | to | $120.00 |
| No. 1 Hard White Shavings, unruled.. | 105.00 | " | 115.00 |
| No. 1 Soft White Shavings | 80.00 | " | 95.00 |
| No. 1 White Ledger.. | 53.00 | " | 65.00 |
| No. 1 Heavy Books & Magazines | 40.00 | " | 42.00 |
| White Blank News.. | 65.00 | " | — |
| Mixed Kraft Env. & Bag Cuttings | 75.00 | " | 85.00 |
| No. 1 Assorted Old Kraft | 45.00 | " | 55.00 |
| Overissue News | 28.00 | " | — |
| No. 1 News | 18.00 | " | 20.00 |
| No. 1 Mixed Paper.. | 12.00 | " | 15.00 |
| Old Corrugated | 30.00 | " | 40.00 |
| Mill Wrappers | 22.00 | " | — |

# MARKETS

BLANC FIXE—Market unchanged, deliveries fair and supplies adequate. Pulp is currently quoted at $77.50 per ton in barrels, car lots at works, and $82.50 l.c.l., f.o.b. works.

BLEACHING POWDER—Market continues tight. Demand firm. Shortages of metal containers. Quotations are unchanged. Prices range from $3.50 to $4 per 100 pound drums l.c.l., works.

CASEIN—Market temporarily unsettled. Buying slow. Current prices on processed acid precipitated casein remain at previous levels and are quoted around 31½ to 33 cents per pound for domestic grades and 30 to 31½ cents for imported grades, f.o.b. shipping point.

CAUSTIC SODA—Market extremely tight. Production unequal to expanding demand. Solid caustic is reported at $2.85 per cwt.; flaked and ground is quoted at $3.25 per cwt. in 400 pound drums, $3.75 per cwt. in 100 pound drums — car lots at works; liquid 50% in tank cars at $2.25 per cwt.; liquid 73% in tank cars $2.35 per cwt. at works.

CHINA CLAY — Market steady, domestic grades in good supply. Domestic filled clay is currently $10 to $13 per ton, car lots, coating clay $15 to $30, imported clay from $18 to $35 export warehouse.

CHLORINE — Heavy demand exceeds available supply. Supply tight. Quantities unchanged. Currently quoted $2.25 per cwt. in single unit tank cars, and $2.55 to $3.75 per cwt. in multi-unit tank cars, f.o.b. works.

ROSIN—Buying slower. Strong resistance to advanced prices. Prices firm. Gum rosin in drums per 100 pounds net, in yard, New York, car lots, B, D, $8.50; E, F, $8.75; G, H, I, K, M, $10.10; N, WG, $10.25; WW, $10.28. Wood rosin, per 100 pounds, net, f.o.b., l.c.l., N. Y., B, $6.45; FF, $7.95; G, H, I, K, M, N, $10.33; WG, $10.43; WW, $10.63; X, $10.73.

SALT CAKE — Demand continues strong with slight improvement in shipments. Prices remain unchanged. Domestic salt cake is quoted at $20 to $26.

SODA ASH — No improvement in supply situation. Heavy demand. Current prices, car lots, per 100 pounds, are as follows: in bulk, $1.10; in paper bags, $1.30; and in barrels, $1.80.

SODIUM BICARBONATE—Supply good. Reported at $1.85 per cwt. paper bags, carload lots.

STARCH—Market firm and active. Production moving steadily. Prices stronger. Increase expected. Pearl grade quoted at $6.52 per 100 pounds, powdered starch at $6.63 per 100 pounds, car lots, Chicago.

SULPHATE OF ALUMINA — Supply ample. Prices firm. Quotations continue unchanged. The commercial grades are quoted at from $1.15 to $1.30 per 100 pounds, in bags, car lots, f.o.b. works. Iron free is quoted at $2 per 100 pounds in bags, car lots, at works.

SULPHUR—Supplies ample to meet increasing demand. Annual contracts are quoted at $18 per long ton, f.o.b. mines; the price f.o.b. at Gulf ports is $19.50 per long ton.

TALC—No improvement seen in domestic market. Demand far in excess of supply. Domestic grades are currently quoted at $21 per ton in mines; Canadian at $35 and up per ton. All prices in car lots.

# DIGESTED

Sweden's trade policy and whole economic policy must for the present be based on the necessity of balancing the country's payments to the dollar area, a situation which may well continue for several years, the Governors of the Bank of Sweden (Riksbank) point out in a report to the Government which has received much attention in the Swedish press. This will result in a very considerable reduction of Sweden's imports from the dollar markets. The reduction cannot be compensated for by importation of similar goods from Europe and will therefore lead to a definite lowering of the living standard in Sweden, compared to what would have been possible under a free exchange of goods. Sweden's production must be increased and its exports directed toward countries with hard currencies.

The idea of bolstering trade with Central Europe by means of further credits is discarded by the Governors. The present situation, they say, even warrants a reconsideration of credits already granted but not yet utilized. Wage increases will not be possible, and it may even become necessary to lower the income level. As regards the social reform program, a pause must now be observed.—*Business News Letter of the American-Swedish News Exchange.*

## Production Ratio Report*

(Production as per cent of six-day capacity)

COMPARATIVE WEEKLY SUMMARIES

| Current Weeks—1947 | | Corresponding Weeks—1946 | |
|---|---|---|---|
| September 20 | 108.6 | September 21 | 105.8 |
| September 27 | 107.0 | September 28 | 106.6 |
| October 4 | 109.5 | October 5 | 107.2 |
| October 11 | 108.4 | October 12 | 105.9 |
| October 18 | 108.3 | October 19 | 105.1 |
| October 25 | *109.7* | October 26 | 106.8 |

COMPARATIVE MONTHLY SUMMARIES

| 1946 | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | June | 104.6 | Dec. | 97.0 | Apr. | 105.1 |
| Jan. | 94.7 | July | 94.0 | Year Avg. | 101.1 | May | 106.2 |
| Feb. | 98.4 | Aug. | 104.7 | 1947 | | June | 106.0 |
| Mar. | 104.4 | Sep. | 101.3 | Jan. | 102.1 | July | 93.5 |
| Apr. | 102.7 | Oct. | 106.4 | Feb. | 105.9 | Aug. | 104.2 |
| May | 100.7 | Nov. | 105.5 | Mar. | 106.1 | Sep. | *102.0* |

COMPARATIVE YEARLY SUMMARIES

| | 1940 | 1941 | 1942 | 1943 | 1944 | 1945 | 1946 | 1947 |
|---|---|---|---|---|---|---|---|---|
| Year to Date | 86.1 | 96.2 | 92.0 | 88.5 | 88.3 | 88.9 | 101.0 | *103.9* |
| Year Average | 85.6 | 97.4 | 90.4 | 87.8 | 88.1 | 89.4 | 101.1 | |

PAPERBOARD OPERATING RATIOS†

| Current Weeks—1947 | | Corresponding Weeks—1946 | |
|---|---|---|---|
| September 20 | 101 | September 21 | 100 |
| September 27 | 102 | September 28 | 101 |
| October 4 | 100 | October 5 | 100 |
| October 11 | 102 | October 12 | 99 |
| October 18 | 101 | October 19 | 98 |
| October 25 | *101* | October 26 | 101 |

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Year Avg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1946 | 90 | 91 | 100 | 99 | 94 | 97 | 89 | 99 | 96 | 100 | 99 | 92 | 96 |
| 1947 | 99 | 103 | 101 | 100 | 101 | 101 | 90 | 99 | *96* | | | | |

* Based on tonnage reported to American Paper and Pulp Association. Does not include mills reporting to National Paperboard Association, except in isolated cases where both paper and paperboard are produced and separate tonnage figures are not readily available. Does not include mills producing newsprint exclusively.

† Per cents of operation based on "Inch-Hours" reported to the National Paperboard Association.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# EDITORIAL

## Swedish Facts

Those who spend time seeking for excitement almost always can be sure to find something that will feed the fire of their appetites. Thus with a brief news story of a week ago which had it that Sweden is going to cut off its markets in Europe, particularly for pulp, in order to accent its shipments to this country, with the inaccurately forecast result that such a policy would depress prices for pulp in this country. Such news always runs faster than the correction which would overtake it, but a consensus of opinion by well-informed sources in New York declares that any appreciable effect from such action as the Swedes are in position to take is apt to remain in the future tense for some time yet to come.

Speaking for Swedish financial interests this week the American-Swedish News Exchange presents some facts and summaries that speak for themselves. They were sent out in the routine course of its service, and have no reference to the news dispatch which caused all the excitement.

Says the Bulletin:

"In a survey of Swedish export activities during the third quarter of 1947, the periodical *Index*, published by Svenska Handelsbanken, states that sales and shipments of cellulose have been very likely throughout the period. At the end of August, inventories of cellulose probably amounted to only about 200,000 tons. There is a definite tendency toward a further rise in prices. In regard to sales to the U. S., most of the prices for the last quarter of the year will range around a minimum level of $145 for strong sulphite pulp and a minimum of $140 for unbleached "kraft" pulp. Still higher prices will probably be obtained on certain other markets. Very few contracts for delivery during 1948 seem to have been made so far. Because of the effect the protracted drought in Sweden has had both on rafting and on the supply of electric power, it is very difficult to estimate the size of next year's production.

"As for paper, there are no difficulties in selling available quantities. The shortage of water power is causing great concern at the Swedish paper mills, and a number of machines have had to be shut down."

The shortage of water and the considerably reduced supply of electric power have caused serious difficulties in Sweden. Recently heavy rainfalls have occurred in the mountains in the North, so that the production of power can be increased by about 250 million kwh. Since the shortage for the entire country during the winter is estimated at about 1,500 million kwh, much rain is still needed. The present rationing scheme is based on an estimated deficit of 800 million kwh.

In the beginning of October, rationing had to be made more rigorous after a turbine at the steam-power plant in Västeras had broken down. The Fuel Commission made further cuts in deliveries of power to ten large industries and about 1,000 minor ones.

## But What Else Is It?

Under a commanding headline that served to arrest attention to his views, on the Pacific Coast, Gordon Hall Caine, British industrialist and paper mill magnate, decried the problem that unfavorable exchange creates when international trade is to be promoted. The difference between dollar value and pound sterling value is frightening, he said, and then he went on to suggest a system under which one Government might say to another, "We have this and this and this; can you give us such and such and such for it?"

He says Britain is so short of woolens to clothe its people that the mills are kept busy turning out mediocre grade stuff. Now a loom, the manufacturer pointed out, can make either cheap or fine cloth. Thus the industry cannot fill its orders for the export of fine woolens for which Britain is famous, and this in turn prevents it from getting the much-needed dollars. The same thing can be said of coal, Hall Caine went on.

Before the war Britain was the biggest coal exporter in the world. "So, you see," he said, "only by export can we bring about a balance of trade, but the very things we could sell at a good price abroad are urgently needed for our people at home. Britain is prevented from getting much-needed modern machinery.

"For example, I have seven paper mills, and on my present trip I have bought some of your machinery for them, but not as much as I would have liked, lacking the dollar exchange. We have plenty of sterling exchange, and again I say that some form of barter might meet the situation.

"Australia and South Africa have dollar exchange and they are buying paper-making machinery. Pretty soon they will have the finest paper mills in the world outside of the United States.

"Thus our British newspapers have to limit themselves to four pages a day—I feel upset when I see your bulky newspapers—because we cannot export coal and woolens. There you are in a nutshell."

But after the headline shall have served its usefulness what has the guest from Britain to suggest as material for barter? His own views, as given in the Los Angeles Times, would appear to put us all right back where we started from, shortages of something to represent the "this and this and this."

W. L. Cook

**Editor**

# SAFE FROM FARM TO MARKET...

The chances of fruits, vegetables, and other perishable foods arriving at their destination crisp, cold, and fresh, have been greatly enhanced by shipment in crates lined with wet-strength paper made with PAREZ Resin 607. For PAREZ Resin 607 imparts such high wet-strength to paper crate liners that they remain strong even though packed in ice and exposed to continuous moisture. Crates have been damaged and broken—yet in many cases the wet-strength paper has held the contents intact. Thus PAREZ-treated paper provides extra protection for produce and reduces waste from spoilage.

Crate liners are only one of the many paper products being given new value and importance because of properties imparted by PAREZ Resin 607. Frozen food locker papers are strong and tear-resistant. Grocery and shopping bags, vegetable and meat wraps, labels for canned goods, barrel liners, and other grocery and food store papers are longer-lasting and more satisfactory when given the advantages of wet and dry strength secured with PAREZ Resin 607.

This same resin also improves fold endurance, printing qualities, and wet-rub resistance of almost any type of paper. Wet-strength paper can be produced by adding PAREZ Resin 607 in the regular paper manufacturing process very simply under Cyanamid's own process.

We shall be glad to supply paper manufacturers with complete data on the use of PAREZ Resin 607 for the production of wet-strength paper crate liners or any of the many other stronger, more serviceable paper products that are in increasing demand today.

**AMERICAN Cyanamid COMPANY**

*Industrial Chemicals Division*

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DISTRICT OFFICES: Boston, Mass.; Philadelphia, Pa.; Baltimore, Md.; Charlotte, N. C.; Cleveland, Ohio; Chicago, Ill.; Kalamazoo, Mich.; Detroit, Mich.; St. Louis, Mo.; Azusa, Calif.; Seattle, Wash. In Canada: Dillons Chemical Company, Ltd., Montreal and Toronto.

**Trade-mark of American Cyanamid Company covering its synthetic resins for use by the paper industry. The processes under which PAREZ Resin is applied in the production of wet-strength paper are covered by U. S. Patent Nos. 2,291,079; 2,291,080; and 2,345,543; and U. S. Patent Application Serial No. 453,032.

SECTION OF THE

TECHNICAL ASSOCIATION
OF THE PULP AND PAPER INDUSTRY

122 E. 42nd ST., NEW YORK 17, N. Y. Edited By R. G. MACDONALD, Secretary

# Super Calender Roll Deflections and Crowns*

By J. B. Gough[1]

The duty of a supercalender is, generally, to improve the surface finish on the paper it receives from the "all metal roll" calender on the paper machine, and to achieve various degrees of surface flatness, smoothness, gloss or reflectance, or combinations of these, to suit the customer's requirements, at as fast an operating speed as possible and with a minimum of breaks, splices, lost time, and waste paper, and, at the same time, to accomplish this with a minimum loss of strength and opacity while retaining a reason- Further, the finish must be as uniform as possible ably high moisture content in the finished sheet. across the entire width and in the length, be satisfactorily durable for the purpose intended, and with, usually, a limited increase in sheet density and reduction in caliper.

Additional requirements may be rapid ink absorption without spreading, smearing, or "strike-through," with a sufficiently soft elastic surface to take good clear type impressions without "skipping" and without fouling the type with loose fiber or mineral coating, if any.

It is the purpose of this paper to discuss only the effect of roll deflections and crowns on the above requirements and, more particularly, their effect on the uniformity of the surface finish across the entire sheet width, and on calender cuts, snap-offs, and broke; all of which are believed to be largely influenced by the roll deflections and crowns and their suitability for the particular number, diameter, face, and rigidity of all the metal and fiber rolls in the stack, as well as for the nip pressures in use and, to a minor degree, the "draw tension" in the sheet and the alternate methods of threading the sheet either directly into and out of the top and bottom nips, or over and under the top and bottom rolls.

## 1. Roll Deflection and Crown

The bottom, and generally the top, roll of a supercalender acts as a simple beam, supported at its ends by its journals and bearings and loaded *uniformly* by the nip pressure along almost its entire face, to which load the weight of the roll itself must be respectively added or subtracted, as the case may be. However, if the nip pressure on the top roll happens to equal the weight of this roll, then it is not a beam and will not bend, and may require little if any crown. It also follows that none of the intermediate rolls act as simple beams and will not be bent and must not be crowned if all their nip pressures are uniform across the face, as their journals and bearings are not arranged to support them in a *vertical* direction, although their bearings must be arranged to hold these rolls in a *horizontal* direction in order to resist the horizontal forces due to the sheet tension and the rolling friction in the nip, which forces will bend each of these rolls in a horizontal direction and in the opposite horizontal direction to the rolls in contact with it; this horizontal bending and deflection of the intermediate rolls (and the other rolls) may be slight however, say between 0.0002 and 0.035 inch, which may not justify crowning them, especially if crowned fly-rolls are used, as well as for other reasons to be discussed in some detail later in Sections 2, 5, and Appendix.

Whether this small horizontal deflection of all rolls, due to sheet tension and rolling friction, is ignored or corrected for by a suitably small crown, it is important to note that if the top and/or bottom roll is incorrectly crowned, then the nip pressures in the stack will not be uniform across the face and this cannot be corrected by crowning one or more of the numerous intermediate rolls, although the relative softness of the uncrowned "fiber" rolls will reduce the effect of this crown error. However, alternately spaced crowned and hollow crowned intermediate rolls, each with crowns equal to the crown error in the top and bottom rolls, will thus provide uniform nip pressures on all rolls, if an *odd* number of intermediate rolls are used when the crown error in both top and bottom roll is identical, and if an *even* number of intermediate rolls are used when the crown error in both top and bottom roll is the same amount, but the top roll crown is too large and the bottom roll crown is too small, or vice-versa. This is a very complicated and somewhat questionable method of correction for incorrect crowns on the top and bottom roll, and is limited to the two cases where the crown errors in top and bottom roll are exactly the same amount, though they may differ in sign, as it involves additional roll wear and power, and may affect the quality and uniformity of the sheet finish across the width. It is of interest to note, however, that if the top and bottom roll crown errors are the same amount and the number of inter-

[1] Member TAPPI; Chief Eng., Mead Corp., Chillicothe, Ohio.
* Presented at the Second Engineering Conference, Hotel Bellevue-Stratford, Philadelphia, Pa., November 3-5, 1947.

mediate rolls odd or even, as specified above, then the fiber rolls will gradually wear and adjust their crowns towards giving a more uniform nip pressure. If, therefore, nip pressure *must* be varied in operation, to suit changing basis weights, finish, or speed, it would appear preferable to have an *odd* number of intermediate rolls when top and bottom roll crowns are both too small, or too large, and an *even* number when one is too small and the other is too large.

### 2. Relation Between the Degree of Sheet Finish and Roll Crown

While this discussion is concerned with the *uniformity* of finish only, principally in the direction of the sheet width and roll face, it must allow for the fact that some type of relative movement between the two adjacent roll surfaces, during their nip contact with the sheet, is a prime necessity for any supercalender type of finish; of course accompanied by the requisite nip pressure, design and softness of the fiber rolls, and also the metal rolls, as well as their surface texture and finish, and, last but by no means least, the specifications of the sheet and the coat, if any. This necessary relative movement of the two roll surfaces in the nip, and maybe the uniformity of sheet finish, can be directly affected by the use made of crown, as a correction for roll deflection, and just how even correct total crown is distributed between the various rolls of the stack while still maintaining a uniform nip pressure.

It is, of course, apparent that if any pair of rolls are pressed together at their nip contact by applying force at their journal bearings, as in a breaker stack, and one of them has no crown, while the other has a sufficient and correct crown to take care of the deflection of both rolls and therefore provide a uniform nip pressure, then the relative movement between the two adjacent roll surfaces during their nip contact with each other, or with the sheet, cannot be uniform across the sheet width, and neither can the degree and quality of the sheet finish, if finish is affected by and depends on the amount of this type of relative movement. It is apparent that this type of relative movement, which may be called "slip," between these roll surfaces must be greatest at the ends and center of the roll face and zero at the "quarter-points" where both roll surface speeds must be exactly the same, at least when both rolls are the same hardness and nominal diameter.

If, on the other hand, each of these rolls has its share, proportional to its nominal diameter, of this same total crown, then the surface speeds of the two rolls will agree at any point in the width and there will be no slip at all, and no finish due to the slip type of relative movement. In fact, if both rolls are exactly the same in diameter, crown and hardness, etc., there will be no relative movement of any type between the two roll surfaces in the nip, and therefore no finish, except for any finish resulting from the compression of the sheet and the possible minute relative movement between sheet and rolls caused by the flow of the sheet away from the region of high nip pressure.

If, however, these two rolls are of different hardness, such as a cast iron roll mating with a paper or cotton roll, then the softer fabric roll will be flattened much more in the nip than will the harder cast iron roll, and this rather minute difference in the surface distortion of the two rolls will result in a greater flow of the material in the fabric roll away from the region of high pressure, resulting in relative movement between the two roll surfaces, which type of relative movement may be called "creep," and results mainly from differences in the hardness of the two rolls, and not, like slip, from a pair of rolls which do not have crowns proportional to their diameters. Creep, therefore, is rarely absent from the nip, unless both roll diameter and hardness are exactly, or nearly, the same for both rolls.

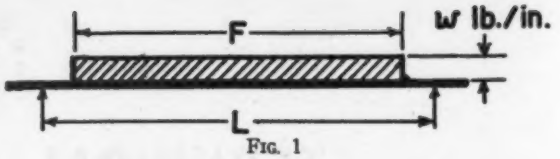

FIG. 1

Supercalender finish must mainly depend upon slip or creep, or both. If finish depends upon slip only, then the finish cannot be uniform across the sheet width because of the nonuniform slip resulting from crowns which are not proportional to roll diameters, and without such crowns there will be no slip. If finish depends upon creep only, then the finish can be exactly uniform across the width if the crowns are correct for uniform nip pressure, and whether or not these crowns are proportional to roll diameters. It should again be noted that only the top and bottom roll can be crowned, except for horizontal roll deflection, if nip pressures are to be uniform, all as discussed in Section 1.

If, as seems somewhat likely, creep has a major effect and slip a minor effect on finish, then for the most uniform finish the top and bottom rolls should be as stiff and rigid as economically advisable in order to reduce their crowns and the nonuniform slip and finish resulting from such crowns, as well as reducing fiber roll wear and power, and increasing the tolerance of the supercalender for a larger necessary range of operating nip pressures.

It would be a major omission to close this discussion on the degree and quality of finish without referring to the very enlightening and somewhat startling discussion on finish in the April 1946 issue of *"The Paper Industry and Paper World,"* by J. A. Van den Akker, in which finish is shown to be the result of a combination of considerable "hydrostatic" compression and still greater shear. While nip pressure is generally considered as a compressive stress in one direction only, this is not true if friction is present between the sheet and roll surfaces, and hydrostatic compression, or equal compressive stress in three mutually perpendicular directions, is much closer to the truth, especially if the thickness of the sheet is small in comparison to the nip width and the metal roll does not have too perfect a "mirror finish"; on the other hand, too rough a metal roll finish is apt to result in "blackening" and loss of opacity, etc., before a satisfactory high degree of surface finish on the sheet is obtained.

### 3. Calculation of Roll Deflection and Crown

The top and bottom roll of a supercalender is a simple beam, freely supported at its ends by its journals and bearings, and loaded uniformly over the entire face of the roll by its uniform weight, and over nearly the entire face by the uniform nip pressure, all as discussed in Section 1, and as shown in Fig. 1.

Because of the action of these loads, the axis of the roll bends and the deflection thus caused in the roll face is usually compensated for by crowning

the roll face by an amount equal to twice the deflection, thus making this face a perfectly straight line at the nip contact with another roll.

The well-known equation, which gives this deflection in terms of the roll diameter, face, distance between center-line of bearings, roll material, and nip pressure ± roll weight, is as follows:

$$\delta = \frac{5\omega F^4}{384EI} + \frac{\omega F^3}{32EI}(L-F) \qquad (1)$$

Where the second term on the right hand side of the equation represents the added deection due to the overhang of the journals, which is appreciable and should not be neglected. Both the nip pressure and roll weight are assumed to act over the whole roll face.

$\delta$ = Deflection of roll at the center of the face, in inches.
$D$ = Outside diameter of roll, in inches.
$d$ = Inside diameter of roll, in inches (if hollow).
$I$ = "Moment of Inertia" of roll, in inch units.

$$I = \frac{\pi}{64}(D^4 - d^4)$$

$F$ = Face of roll, in inches.
$L$ = Distance between center-line of self-aligning bearings, in inches.
$E$ = "Modulus of Elasticity" of roll material.
C.I. = 15,000,000, St., = 30,000,000 (app.).
$\omega$ = Nip pressure in pounds per inch of face ± weight of roll per inch of face.

If all the above dimensions, forces, and other factors in equation (1) are known, except the deflection $\delta$, then this latter can be found with quite reasonable accuracy and a minimum of effort. However, the $E$ for cast iron is not quite constant, but increases with the bending stress, so that, if the relation between stress and $E$ is known, a modified value of $E$ should be used.

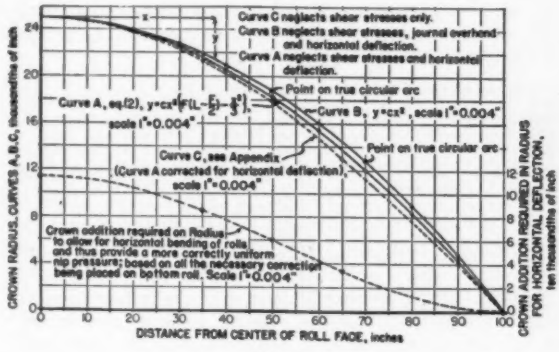
Curve C neglects shear stresses only.
Curve B neglects shear stresses, journal overhend and horizontal deflection.
Curve A neglects shear stresses and horizontal deflection.
Point on true circular arc
Curve A, eq (2), y=cx⁴(FL-F²/2-x²/3), scale 1"=0.004"
Curve B, y=cx², scale 1"=0.004"
Point on true circular arc
Curve C, see Appendix (Curve A corrected for horizontal deflection), scale 1"=0.004"
Crown addition required on Radius to allow for horizontal bending of rolls and thus provide a more correctly uniform nip pressure; based on all the necessary correction being placed on bottom roll. Scale 1"=0.004"
CROWN RADIUS, CURVES A, B, C, thousandths of inch
CROWN ADDITION REQUIRED IN RADIUS FOR HORIZONTAL DEFLECTION, ten thousandths of inch
DISTANCE FROM CENTER OF ROLL FACE, inches

FIG. 2

While equation (1) is considered sufficiently accurate for most cases, it is not absolutely exact, and gives a deflection which is slightly *less* than the correct deflection, due to the neglect of the effect of shearing stress and other three dimensional stresses on the deflection. Calculations involving these minor stress effects on the deflection are exceedingly complicated, but for the average solid calender roll having a diameter and stiffness commensurate with its width of face, say $D = F^{3/4}$, the value of the deflection, as found by equation (1), should be multiplied by 1.0003 approximately. A further correction for the weight of the journals, or for a rigid, non-aligning bearing, could be made, but this involves unnecessary complication and effort. Equation (1) with the above modifications and minor corrections is only true when the bending stresses, etc., in the roll are all within the elastic limit of the roll metal, and when the axis of all rolls in the stack are parallel and in the same vertical plane, which latter may not be the case, even if horizontal bending is ignored, due to clearance between journals and bearings, and between bearings and stack frames, etc.

## 4. Shape of the Crown Curve

Not only should the crown at the *center* of the roll face be correct, and so as to correct for the roll deflection at this particular point in the face, but it should be similarly correct for *all* points across the face, and thus the shape of the crown curve should be exactly the same as the shape of the roll deflection curve. With a uniformly loaded roll, as per Fig. 1, the roll axis is not bent in a circular arc, nor in a simple parabola in $x^2$, although it seems likely that all, or at least most, roll grinders with automatic attachments for grinding crowned rolls are designed to reproduce either the circular arc or the simple parabola in $x^2$, as it may well be that one or the other of these two curves are close enough to the truth for relatively small crowns and are the best that can be provided without very complicated mechanisms on the grinder, which may be neither practical or justified. However, neither of the above curves are quite correct.

Based upon the loading and other conditions as in Fig. 1, and in agreement with equation (1), the correct shape of the crown curve, if the deflection due to shear is neglected, is defined by equation (2), as follows:

$$Y_x = \frac{\omega x^2}{8EI}\left\{F\left(L - \frac{F}{2}\right) - \frac{x^2}{3}\right\} \qquad (2)$$

Where $x$ = Distance from center of roll face, in inches. (Note: origin at center.)
$Y_x$ = Deflection, also half the crown, at point x, in inches.
All other factors being the same as for equation (1).

An inspection of this equation (2) will disclose that it is not a simple parabola in $x^2$, but in $x^4$; neither is it a circular arc.

In order to visualize what difference there may be in the shape of the crown curve, depending upon which of the above equations is used as a basis for grinding the roll crown, very exact calculations of the shape have been made and Fig. 2 shows the relation between two of them, namely, the $x^4$ parabola curve A as per equation (2) and the $x^2$ parabola curve B. Both these curves are for a roll face of 200 inches and a crown of 0.050 inches, which is about the crown required for a cast iron roll of this face, more or less, depending upon the roll diameter and nip pressure. It will be noted that the maximum difference between these two curves occurs nearly at the quarter-points and that equation (2) gives about 0.0015 inch less *crown* at this point than does the $x^2$ parabola.

The circular arc curve was also calculated very exactly and gave exactly the same crown as the $x^2$ parabola at 50 inches, and about 0.0005 inch less *crown* at 70 inches from the center of the face. The circular arc curve lays so close to the $x^2$ parabola that it is not shown in Fig. 2, but only the two points at 50 and 70 inches.

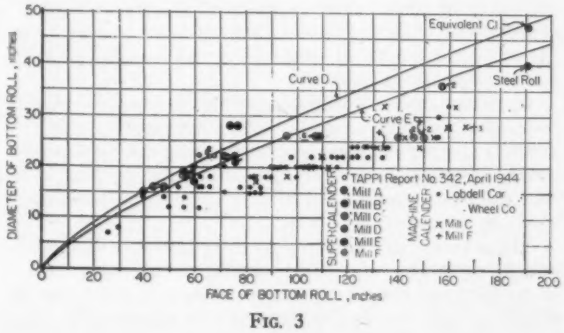


FIG. 3

If it be assumed from Fig. 2 that the difference in crown shape between these three curves is negligible when there are fiber rolls in the stack to reduce the effect of these small differences, it must not also be assumed that the additional bending and crown due to the overhanging journals, as included in equation (1), is also negligible, as this is not the case. It should be further noted that as the width of calenders increase, and generally the crown also, the above differences in crown shape also increase and may not be as effectually absorbed by the fiber rolls as would be the case with relatively narrow calenders.

### 5. "Calender Cuts" and "Snap-offs". (Also "Splices", "Broke" and "Lost Time")

It appears to be the very general opinion of both operators and designing engineers that an increase in the width of a stack is very likely to result in an increase in operating difficulties, such as less finish, more calender cuts, snap-offs, splices, broke, and lost time, even on the same sheet from the same paper machine, and even although the narrow stack takes only one-half, or one-third, of the paper machine width at a time, whereas the wide stack takes the full paper machine width. This disadvantage of the wide stack is probably believed to be generally the result of an imperfect sheet, rather than an imperfect stack, whereas the reverse is just as likely to be the case.

While it is very probably true that the difficulty of forming a sheet of uniform basis weight and drying it to a uniform moisture content does increase with the paper machine width, even at the same speed, this increased difficulty is at least greatly reduced by the greater refinements in paper machine design usually associated with the wider paper machines. However, it is probably true that a narrow supercalender taking the full width sheet from a narrow paper machine has an easier sheet to finish than a wide supercalender taking the full width of a wide paper machine; this does not necessarily mean, however, that a narrow supercalender taking only part of the full paper machine width has an easier sheet to finish than a wider supercalender that will take the full width of the same paper machine, unless the sheet is very perfect and/or the narrow supercalender is kept entirely on the same roll position in the paper machine "log" roll, say front, back, or middle, as the case may be.

If the same narrow supercalender has to deal with rolls from the front, middle, and back of the paper machine log roll, more or less in rotation, it may have a more difficult sheet to finish than the full width supercalender, which latter can accommodate itself more readily to the more or less constant inaccuracies of the full width sheet produced by the paper machine, by means of local air cooling of the calender rolls, fiber roll wear and sanding, or by adjustment of the draw tension and paper carrying roll alignment. Certainly it is true than even an absolutely perfect sheet can be expected to give some trouble on a supercalender, especially a wide one, unless the rolls are so stiff that the roll deflections and crowns are really negligible and all the rolls are in line.

Unfortunately, it is not possible to entirely eliminate the bending of rolls, either vertically or horizontally, or the crowns, or the working clearances between journals and bearings, and between bearings and calender frames, but all may be reduced in most cases if the expense is warranted.

The unavoidable bending of the rolls both vertically and horizontally, and the resulting necessary crowns to compensate for this bending, at least in the vertical direction, can be shown to result in appreciable distortion, or unequal stretching, of the sheet, so that the edges are stretched more than the center of the sheet is most cases, or vice-versa, except in rare cases where a happy coincidence of roll deflections, crowns, draw tension, sheet leads, and journal and frame clearances may possibly result in a uniform sheet tension over the entire sheet width.

In order to show that the sheet can be, and probably usually is, stretched unequally, and generally more at the edges than at the center, it is only necessary to calculate the horizontal forces acting on each of the rolls and the resulting horizontal deflections, as well as to calculate, or assume, the deflections and crowns resulting from the vertical forces of roll weights and nip pressures on the top and bottom rolls only. From this information it is simple to calculate the exact distance the sheet must travel through the stack of rolls from the time it touches the top roll until it leaves the bottom roll, and if this total distance is not exactly the same at the edges of the sheet as it is at the center of the sheet, due to roll deflections and crowns, then the sheet must be stretched unequally and distorted, resulting in unnecessarily higher local tension at the edges, or center, with increased danger of snap-offs, as well as forcing the sheet to wave, ridge, or wrinkle on the rolls and in the nips, with increased danger of calender cuts.

To prove the point it is therefore best and, in the long run, less complicated to make an analysis of a specific supercalender design, so that this difference in the length of the sheet path through the stack can be calculated, shown, and appreciated, as well as disclosing all the various factors that contribute to making this difference large and dangerous or small and safe. This specific design is as follows:

One hundred and fifty-seven inches wide, ten-roll supercalender, 30-inch dia. top roll, three 14-inch dia. metal, and five 20-inch dia. fiber intermediate rolls, 36-inch dia. bottom roll, all metal rolls solid C.I., 2400 pounds per inch maximum nip pressure, and 300 hp. motor at 1200 f.p.m. Draw tension in sheet entering stack assumed to be 2 pounds per inch. Coefficient of antifriction bearings assumed to be = 0.005 at journal dia., and coefficient of rolling friction roughly checked and adjusted to = 0.014 at nip contacts. $E$ = 15,000,000.

With the above conditions, and using equation (1), the top roll crown = 0.0824 inch, intermediate roll crowns, as usual, = 0.000 inch, and bottom roll crown = 0.0524 inch. It should be noted that these crowns are based entirely on the vertical loading alone, and on the resulting vertical deflections of the top and bottom roll only, and that they would provide uniform nip pressures across the face (and unbent intermediate rolls), except that the neglected deflection due to shear stress and horizontal bending would slightly add to, and crossed rolls slightly subtract from, the above required crowns.

It is important to also note that the crown required on the top roll is very sensitive to the main nip pressure on the bottom roll. If this nip pressure is reduced from 2400 to 1200 pounds per inch, then the required top roll crown is reduced from 0.0824 to 0.030 inch; and if reduced to about 600 pounds per inch, the top roll crown should be nearly 0.000.

It may not be fully appreciated how large the horizontal forces bending the rolls, and especially the lower intermediate rolls, may be, and these are relatively slender and not particularly designed to resist these horizontal forces. The horizontal force bending any particular intermediate roll is equal to twice the horizontal sheet tension on this roll (∴ say 1 to 4 pounds per inch), plus slightly less than twice the force requiredto rotate this particular roll, together with all the rolls above it, against the combined resistance offered by the rolling friction at all these nips and the bearing friction at all these roll journals. If it is assumed that

the 300 h.p., motor is fully loaded and delivers at least 85% of its power to the main bottom roll, then the force rotating the bottom intermediate roll is about 37.1 pounds per inch, and the horizontal force bending this roll is = 37.1 × 2 + 1 = about 75 pounds per inch of face. The horizontal force bending the main bottom and top roll is, respectively, about 37.5 and 11.2 pounds per inch, assuming draw-tension to reel is about 0.2 pound per inch.

While the exact equations giving the horizontal force bending the various rolls in this ten roll stack are too numerous, long and complicated to be included here, and the calculations long and tedious, especially as they involve the proper frictional co-efficient at nips and bearings and must check with the proper horsepower input, the resulting horizontal deflections of the top, average intermediate, and bottom roll is respectively about 0.00025, 0.0218, and 0.00039 inch. Unfortunately, as mentioned earlier in this discussion, these horizontal forces resulting from sheet tension, nip and bearing friction all act in the same horizontal direction on any particular roll, and in the opposite direction on both adjacent rolls, so that all adjacent rolls in the stack deflect in opposite horizontal directions, and thus all tend to slacken the sheet in the middle of its width, or, as stated earlier, reduce the length of the sheet path at the center of its width compared to the length at the edges. The above horizontal deflections are based on the sheet passing over the top and under the bottom roll.

Based upon the above horizontal deflections, the difference in sheet length in contact with the stack, comparing the length at center and edge of sheet, is very closely = 2(0.00025 + 0.0218 × 8 + 0.00039) = 0.350 inch, which represents a very appreciable slackening in the center, quite capable of serious sheet distortion and uneven tension, with their accompanying evils. However, the crowns on the top and bottom roll tend to tighten the center of the sheet, especially if the draw lead is over the top and under the bottom roll, and this difference $= \frac{\pi}{2}$ (0.0824 + 0.0524) = 0.212 inch about. The net slackening on the center of the sheet is thus = 0.350 —0.212 = 0.138 inch.

However, some spot checks appear to indicate that operators generally use not more than about two-thirds of the theoretical crown calculated by equation (1); in this case the slackening at the sheet center = 0.350 — 0.141 = 0.209 inch. Also, the theoretical crowns as calculated by equation (1) should be increased by about .03% to allow for shear deflection, in which case the slackening at center may be = 0.350 — 0.141 = 0.210 inch, approx.

It should be clearly noted that this greater tension and stretching of the edges of the sheet, compared to the center, practically all takes place in the relatively short distance between the top and bottom nips of the stack, between which two nips the sheet is fairly securely held; consequently the increased tension in the edges may result in snap-offs, and the relatively slack and easily wrinkled condition of the sheet in the center may result in calender cuts, unless suitable fly rolls, or nip-out rolls, possibly wormed or crowned, are used to correct this dangerous condition.

Even if the very small additional crown, 0.0001 inch or less, required to correct for horizontal bending, is added to each roll to give more correctly uniform nip pressures, it would reduce the shortening at the center by less than 0.002 inch, and is therefore unimportant from this point of view. However, if all eight intermediate rolls are made twice as stiff, by changing the three 14 inch dia., C.I. rolls to steel and increasing the diameter of the steel core in the fabric rolls correspondingly, the horizontal deflection of these eight rolls would be reduced by 50%, thus reducing the difference in length of sheet path to: 2(0.00025 + 0.0109 × 8 + 0.00039) = 0.176 inch which, after allowing for the opposite effect of the crowns, would now stretch the sheet at the center by: 0.212 — 0.176 = 0.036 inch, whereas previously the edges were stretched 0.138 inch. It is therefore quite possible, at least theoretically, to design a stack that causes no distortion of the sheet due to horizontal deflection of the rolls, if this is desired.

There is still one more factor that may cause a very much greater sheet distortion than that resulting from the above horizontal deflection of the rolls. If it be assumed that the working clearance between journal and bearing, as well as between bearing and frame guide, is each 1/32 inch for each of the eight intermediate rolls, even if the top and bottom rolls have no such clearance, it is clear that the end of each intermediate roll may move 1/32 inch off true center in either horizontal direction and that there is no very apparent reason why it will not do so; indeed, there is ample evidence that this frequently happens, as indicated by heavy end thrust that can be only the result of crossed rolls, although it is by no means easy to show why adjacent rolls must cross, especially if the frames are true and the sheet properly centered on the roll face, but it certainly does frequently happen. If it does occur, then one edge of the sheet must be stretched ½ inch and the other edge slackened ½ inch, or a total of 1 inch difference in the length of the two edges. Even if these clearances and this difference is reduced by 50% it is still a serious distortion and it occurs between the top and bottom nips and cannot be properly corrected for by adjustment of the paper carrying rolls, but may be by adjustment of the fly rolls, providing this crossed roll condition does not change from time to time as it may do. Very true frame guides and minimum clearances are therefore indicated, and it would seem that the "open" frame with exactly horizontal links equipped with minimum clearance antifriction bearings has some advantage in this respect.

While this crossed roll condition does result in providing an "additional crown effect," and the sum of the normal theoretical crowns on top and bottom roll, as per equation (1), should be correspondingly reduced, this total reduction is less than 0.001 inch, so that it is more or less negligible and does not furnish any adequate explanation of the difference between theoretical and practical crowns mentioned earlier in this section. While it is of no practical importance in this discussion, the crown required to correct for a pair of crossed rolls is negative and the crown curve is hyperbolic, not parabolic as in the usual case.

The crossing, as well as the horizontal bending and deflection, of the rolls, and hence the resulting distortion of the sheet, can theoretically be entirely eliminated by horizontally offsetting the roll bearings in the frame guides so that the horizontal resultant of the then slightly inclined nip pressures exactly balances the horizontal forces of sheet tension, rolling and bearing friction, but this is not a simple or very practical solution, even for given nip pressures, because of the small offset that may be required and it being a different amount for each roll in the stack.

While there are several other important factors that require very careful consideration and analysis by both the designer and operator, including the more or less unknown exact conditions in the nip, such as rolling friction, creep, nip width, maximum and average nip pressure in pounds per square inch across the nip width and the effect of these on the sheet thickness and finish, as well as the detail design and manufacturing technique of the fabric rolls, etc., all this is outside the scope of the title of this discussion.

That stress will produce strain is a universal fact, and a very advantageous fact, even in supercalender design, where strain is absolutely necessary to produce finish in the nips and to take the shock of paper wads passing through the nips, etc. However, excessive strain, or roll deflection, can be a decided obstacle to satisfactory operation, as the above indicates, and there is at least some indication that it could be reduced with advantage. This can only be determined definitely as a result of operating experience which, in time, will gradually result in a most efficient and economical design.

The diameter of the bottom roll and the face of several supercalenders (and some machine calenders) as actually made in the past, which were presumably more or less satisfactory in service, is given in Fig. 3. Of course, these represent only a very small fraction of all the stacks made, and may thus not be truly representative. In the case of the supercalenders, they are all five to ten roll stacks, for many different kinds of paper, speeds, and nip pressures, and probably most have solid C.I., bottom rolls; however, one large stack, as noted in Fig. 3, does have a steel bottom roll.

Since it is clear that roll deflections and crowns will generally result in sheet distortion, except as a result of a balance by chance or by a very careful and accurate analysis such as attempted above for the specific design of a 157-inch supercalender, it would seem reasonable and logical to assume that, unless actual operating experience indicates otherwise, the necessary crown on the bottom roll of a wide supercalender should not exceed twice that on a satisfactory narrow stack of half the width, at the same nip pressure, especially as the larger rolls on the wider stack may actually require more nip pressure to produce the same degree of sheet finish at the same speed. This limitation should also apply to all the other rolls of the stack; indeed, it would seem that it may be more important to make the intermediate rolls stiffer than it is in the case of the bottom roll, unless the bottom roll is C.I., and the intermediate rolls are steel. On this basis of crown being proportional to width at the same nip pressure, $D = CF^{\frac{3}{4}}$ approximately, neglecting the effect of journal overhang and shear deflection, both of which have a greater effect on crown in a narrow stack and may therefore offset a somewhat increased nip pressure possibly required on a wide stack for the same degree of finish at the same speed. Curve D, which assumes that a 30 inch dia., bottom roll is about right for 100 inches width, or $D = 0.949\ F^{\frac{3}{4}}$, can obviously be considered as amply safe, while curve F, which assumes that a 26.5 inch dia., bottom roll is about right for 100 inches width, or $D = 0.839\ F^{\frac{3}{4}}$, might be considered as providing minimum safety, especially if the data on past supercalenders in the 0 to 100 inches wide group are given greater weight than the 100 to 160 inches wide group, since the latter have probably been developed and the width increased more rapidly and indicate a tendency to keep down capital cost at the expense of satisfactory operation, which may partly account for some existing pessimism in regard to wide stacks. However, it is difficult to explain the reason for the very much smaller bottom roll diameters in the machine calenders of all widths, especially as correct crowns would appear to be more necessary with the hard nips of the all metal roll stacks. Possibly, the reason is because of lower nip pressures, or less range in nip pressures and operating tolerance, on machine calenders.

While horizontal roll deflection has only a very slight effect on crown, it is very likely to have a more appreciable effect on crown shape, and a still more appreciable effect on sheet distortion, unless this horizontal deflection, or its effects, is eliminated or reduced by one or other of the means discussed. In order that these earlier conclusions can be carefully scrutinized, the following additional discussion is presented.

If the axes of a pair of rolls, in pressure contact, are in the same vertical plane, and one roll rotates the other, each roll will deflect horizontally in opposite directions, and, if this contact is to be maintained at uniform nip pressure, crown must be provided.

$$C = (E^2 + A^2)^{1/2} - E \qquad (3)$$

Let $E$ = Sum of radii of both rolls; in contact before horizontal bending.
$A$ = Sum of the horizontal deflection of both rolls, say, at center of face.
$C$ = Total clearance between rolls, say, at center, after bending and before crowning.

In the specific design of a ten roll 157-inch face supercalender discussed earlier, the carefully calculated horizontal force bending each roll, starting at the top roll is 11.24, 21.82, 28.99, 38.34, 43.85, 50.96, 58.23, 66.23, 72.85, and 37.1 pounds per inch of face; average = 47.66 pounds per inch of face. The resulting horizontal deflections at the center of the face of each roll is 0.00025, 0.00998, 0.01326, 0.01753, 0.02006, 0.02331, 0.02663, 0.03029, 0.03332, and 0.00039 inch, and the clearance between rolls, which must be "filled" by crown, is 0.000002, 0.000015, 0.000027, 0.000041, 0.000055, 0.000062, 0.000095, 0.000119, and 0.00002 inch, giving a total clearance of 0.000436 inch for the entire stack. The total additional crown required to correct for all the horizontal deflections is therefore 0.000872 inch, which may be added to the top or bottom roll, split between them, or more correctly split in the proper proportion between all ten rolls.

The size and shape of this additional crown curve, due to horizontal deflection, can be determined by combining equations (2) and (3). An approximate similar crown curve for a 200 inch face stack is shown dotted at the bottom of Fig. 2; on the assumption that the diameter and stiffness of the rolls in the 200 inch stack are the same as in the 157 inch stack. In this curve the additional crown radius is shown to a scale of 2500 times full size, in order that its very different shape can be clearly noted.

The dotted curve C in Fig. 2 shows the approximate alteration necessary in the shape of the previously discussed curve A (per equation 2) to take care of the horizontal deflection and still provide a uniform nip pressure, on the assumption that *all* this additional crown is placed on the bottom roll. It will be noted that curve A, a parabola in $x^4$ gives 0.0015 inch too much crown at about the quarter points, while curve B, a circular arc or parabola in $x^2$, gives 0.003 inch too much crown.

# Interrelation of Color Specifications*

By Dorothy Nickerson[1]

**Abstract**

*The interrelation of color specifications for standard reference material is discussed in three sections. Section 1 relates to various ways of graphing or transforming I.C.I. data: (x, y)—diagram; Judd U.C.S. diagram (1932-5); MacAdam U.C.S. diagram (1937); Breckenridge and Schaub rectilinear U.C.S. (1939); Scofield (1940); Adams (1940); Moon and Spencer (1943); Saunderson and Milner (1944). Section 2 lists several sets of standard reference material by which conversions may be made, or for which data into terms of specifications recommended in ASA-Z44 standard are aavilable in whole or in part: Dominant wave length—purity; Munsell; ISCC-NBS; Ostwald; TCCA standards; Maerz and Paul Color Dictionary; Ridgway; Lovibond glasses; Wratten filters. Section 3 reviews the problem of color tolerance specification as it relates to interrelation of color specifications, and includes a summary table of formulas developed for tolerance work.*

Explanations have been given in the preceding papers of this symposium of the various types of color standards, color measurements, and color systems that are variously used in industrial and scientific laboratories.

The simplest standard is one that the United States Department of Agriculture calls a physical or practical form of standard. For raw cotton of American upland varieties there are now, in February 1947, 32 grades. Thirteen of these are represented by cotton put up for public distribution in practical forms or grade boxes; the other nineteen grades are described by reference to the thirteen physical types. Many industries operate on standards of this sort. In fact, such standards are the foundation of much trading in color of various products, and it is quite probable that material standards should be ranked at the top when listed for their commercial usefulness.

Then there are standards in which color is separated from the product and presented by itself on cards, chips, blocks, or other forms, as in the standards for kitchen and bathroom fixtures put out by the National Bureau of Standards. There are times when such standards may be presented on materials similar to those in which the color will be used, as the color standards which the Textile Color Card Association of the United States, Inc., put out as dyed fabrics, or of paint standards put out as paint on flat backgrounds.

Then there are systematic arrangements of color on charts and diagrams, where the medium may differ considerably from the medium of the sample for which a color comparison is to be made. Advantages are gained by the more systematic arrangements, but the disadvantages of comparing different surfaces and materials increase. The ultimate in a systematic arrangement of color is one that helps an individual to think easily in color and provides him with a complete and easily applied notation that is valid and useful for recording all colors, whether available now or not yet developed, in terms of attributes and scales that are identifiable and easily related by visual means. If such a systematic arrangement of colors were available in the form of the objects to be graded, and in steps small enough to allow accurate interpolation in color space, then there should have been little need for this meeting today.

If the manufacturer of shiny red plastic handbags mentioned in Mr. Evans' talk could go to his shelves and take down a set of thirteen bags which, when viewed under standard conditions, would provide him with a standard color and twelve samples that represent his tolerance (these tolerance samples exhibiting equal color differences from the standard in every direction possible), then he might not find it too difficult to train inspectors to pass or fail the bags with considerable uniformity of judgment. However, standard conditions, in which the gloss factor would be held constant, would be a necessity unless the samples were to be multiplied by the number of gloss variations. Add to this the difficulty of maintaining the permanency of color and finish in the standard bags, and it is no wonder that the training of most successful color graders has been on the job itself, their chief qualification consisting of judgment and memory as to the size of color differences that should pass or fail in any given situation.

When color standards are used by industry, they are more and more being measured in one of the three ways outlined by Mr. Evans. The results of

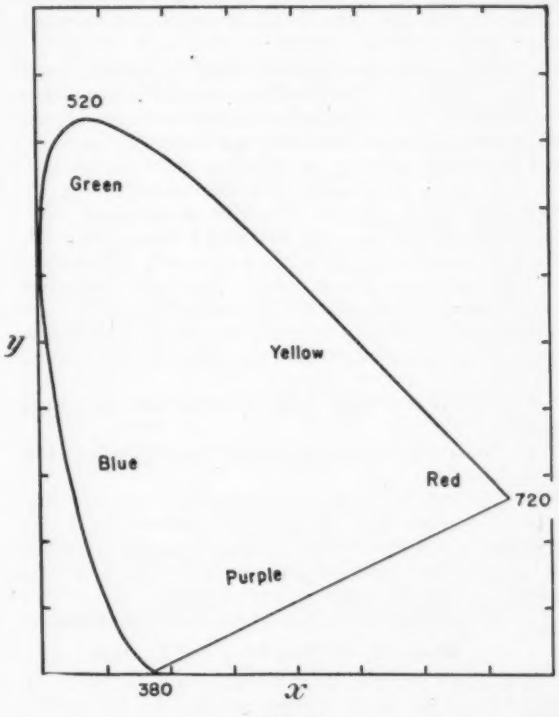


FIG. 1

I.C.I. (x,y)—Color Mixture Diagram with Spectrum Locus, Reds through Yellows, Greens, and Blues, from 720 Millimicrons to 380 Millimicrons. The Straight Line Connecting the Ends of the Spectrum Encloses the Region of Purple and Red-Purple Colors Not Represented in the Spectrum.

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such measurements are sometimes kept on file in terms of instrument readings or, more and more often, are being converted to terms of some form of color notation or specification such as has been described by previous speakers today.

Perhaps the chief use of the I.C.I. system is the fact that it is an internationally used and understood method of color specification. Certainly it does not tell one how a color looks to an average observer. Nor does the spacing on an I.C.I. diagram, whether plotted in trilinear or rectilinear coordinates, bear any resemblance to equal color difference intervals unless

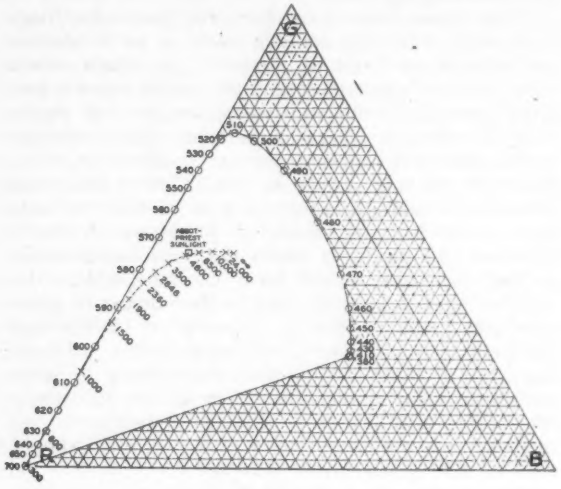


FIG. 2
**Judd's Uniform Chromaticity Scale (U.C.S.) Diagram.**

some sort of transformation is made, either by use of conversion equations or by direct projective transformation.

Yet because of the I.C.I. system it is possible today to interrelate color specifications of many sorts—those based on material standards, whether in the same or a different media as that of the raw cotton or the shiny red bags that we may be grading. It is the purpose of this paper to present information regarding the interrelation of color specifications of standard reference material so that the individual unacquainted in the field may find in one place as much information as it has been possible to collect. Since more and more often color specifications are transformed for the purpose of specifying or meeting color tolerances, the problem of color tolerance specification will be reviewed.

The discussion that follows is divided into three sections:

1. Various ways of graphing or transforming I.C.I. data.

2. Equivalents, in terms either of I.C.I. or of Munsell, of several sets of standard reference material. (Since most of these are too voluminous for inclusion in detail, they are described, with full reference to where the detailed data may be found.)

3. The problem of color tolerance specification.

### 1. Methods of Graphing I.C.I. Data

It is usual practice in this country to specify I.C.I. data by the use of $Y$ for luminance, and $(x, y)$ for chromaticity. The usual I.C.I. $(x, y)$—chromaticity diagram is shown in Fig. 1, with the spectral locus plotted from the reds beginning at 720 m$\mu$, through the yellows to greens near 520 m$\mu$, then through the blues to 380 m$\mu$. The nonspectral region which includes the purples and red purples is enclosed by the straight line which connects the red and blue ends of the spectrum locus. Data for plotting the spectrum in the diagram are provided in tabular form in Resolution 5 of the original I.C.I. report on colorimetry *(6, 27, 37)*

In the period 1932 to 1935, Judd studied experimental data on chromaticity sensibility and in 1935 described *(19)* a Maxwell triangle using a "circle construction" for relating chromaticity sensibility data. This uniform chromaticity scale (U.C.S.) diagram is plotted on trilinear coordinates R, G, B to which I.C.I. data may be transformed by the use of the following equations:*

$$\begin{aligned} \bar{r} &= 3.1956\,\bar{x} + 2.4478\,\bar{y} - 0.1434\,\bar{z} \\ \bar{g} &= -2.5455\,\bar{x} + 7.0492\,\bar{y} + 0.9963\,\bar{z} \\ \bar{b} &= 1.0000\,\bar{z} \end{aligned} \quad . \qquad (1)$$

When the circles of this U.C.S. diagram, shown in Fig. 2, are transformed to the I.C.I. system they result in the ellipses shown in Fig. 3, thus indicating the relation of the spacing on this diagram to equal color-sense intervals.

In 1937 MacAdam *(24)* discussed projective transformations of I.C.I. specifications. Any one who plans to work out such transformations should consult this paper, for in it Dr. MacAdam gives the general equations necessary, and interpretations for the eight independent constants for transformation from I.C.I. to other coordinate systems. The tristimulus values, $U, V, W$, of any sample expressed in terms of any new set of unitary stimuli can be computed from the I.C.I. tristimulus values, if the nine values in the following equations are known:

$$\begin{aligned} U &= a_1X + a_2Y + a_3Z \\ V &= a_4X + a_5Y + a_6Z \\ W &= a_7X + a_8Y + a_9Z \end{aligned} \qquad (2)$$

An example of the use of the methods described

* This system was more closely allied to the O.S.A. coordinate system in use at the time the studies were first made. O.S.A. conversions could be made by the following coefficients:

1, 0, 0.1
0, 1, 0.1
0, 0, 0.2

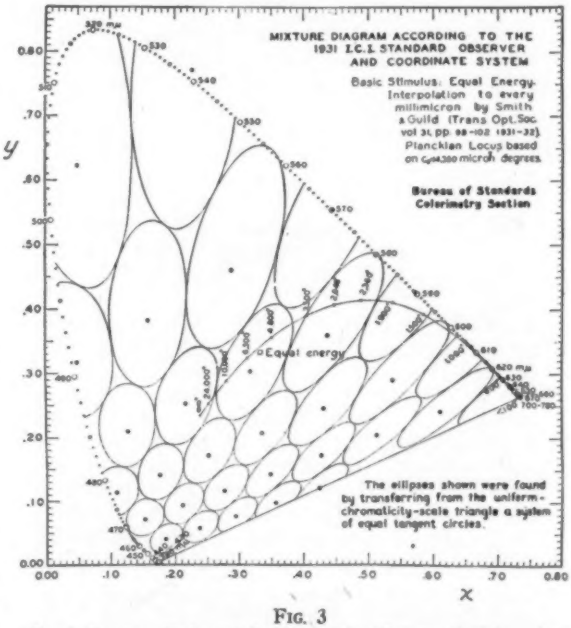
MIXTURE DIAGRAM ACCORDING TO THE 1931 I.C.I. STANDARD OBSERVER AND COORDINATE SYSTEM
Basic Stimulus: Equal Energy. Interpolation to every millimicron by Smith & Guild (Trans. Opt. Soc. vol 31, pp. 99–102 1931–32). Planckian Locus based on $C_{4,800}$ micro degrees.
Bureau of Standards Colorimetry Section
Equal energy
The ellipses shown were found by transferring from the uniform-chromaticity-scale triangle a system of equal tangent circles.
y
x

FIG. 3
**Equal Tangent Circles of Judd's U.C.S. Diagram Transformed to Ellipses on the I.C.I. (x,y)—Diagram.**

is provided by a very simple transformation of I.C.I. specifications to a rectangular coordinate system in which the shape of the spectrum locus resembles that of Judd's U.C.S. diagram, while the luminosity coefficients remain 0-1-0. With a few modifications the following simple transformation equation is developed:

$$u = 2x/(6y - x + 1.50)$$
$$v = 3y/(6y - x + 1.50) \quad (3)$$

From this the following may be derived:

$$U = 2/3X$$
$$V = Y$$
$$W = -0.5X + 1.5Y + 0.5Z \quad (4)$$

The locus of the spectrum colors corresponding to the above equations are shown in the solid curve of Fig. 4; that of Judd's U.C.S. diagram by the broken line. The nature of the MacAdam transformation is shown in Fig. 5 where lines representing constant values of $x$ converge through the point $u=0.0$, $v=0.5$; and lines of constant y converge through the point $u=-2.0$, $v=0.0$.

In 1939 Breckenridge and Schaub *(5)* transformed Judd's U.C.S. triangle to the system of rectangular coordinates illustrated in Fig. 6, the equal energy point being placed at the center of the coordinate system. The first quadrant contains only greens, the second blues, the third purples, and the fourth reds and yellows. Transformation equations for I.C.I. into R.U.C.S. are given both for transforming tristimulus coefficients, and trilinear coordinates:

$$x' = 0.82303x$$
$$y' = -2.32804x + 6.44609y + 1.36896z \quad (5)$$
$$z' = +2.96827x + 2.24750y - 0.55176z$$

$$x' = \frac{0.82303x + 0.82303y - 0.82303}{1.00000x - 7.05336y - 1.64023}$$
$$y' = \frac{3.69700x - 5.07713y - 1.36896}{1.00000x - 7.05336y - 1.64023} \quad (6)$$

Tables for use in transforming I.C.I. into R.U.C.S. coordinates (19 pages) have been prepared by Mr. Breckenridge for every 0.01 $x$ and $y$. A 3-page table for transformation of linear equations has also been prepared. These should be very useful to anyone who uses the R.U.C.S. diagram.

In 1944 Farnsworth, at the U. S. Submarine Base, New London, Conn., made a projective transformation by setting up points representing a circle of Munsell 5/5 colors on the I.C.I. diagram, then manipulating strings representing lines of constant $x$ and $y$ values, until the points representing the Munsell colors showed a minimum deviation from circularity. Such a diagram has the advantage that the data do not have to be transformed if the $x$ and $y$ scales are spaced as shown in Fig. 7. Although this diagram has some of the appearance of the diagram in Fig. 5 it is an improvement as regards uniform spacing as judged by equi-spacing of the Munsell samples—the criterion that is most widely used for judging the effectiveness of U.C.S. charts.

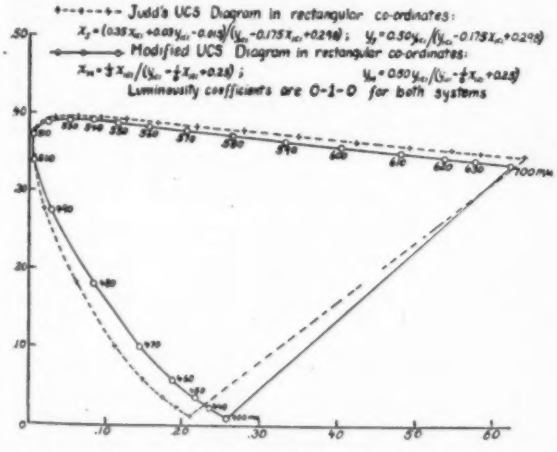
Judd's UCS Diagram in rectangular co-ordinates:
Modified UCS Diagram in rectangular co-ordinates:
Luminosity coefficients are 0-1-0 for both systems

FIG. 4

**MacAdam's Modified U.C.S. Diagram. The Loci of Spectrum Colors Shown by the Solid Line Accord with Transformations in Equations 3 and 4. The Broken Line Represents a Spectrum Locus Having the Same Shape as That Derived by Judd. Luminosity Coefficients in Both Cases Are 0-1-0.**

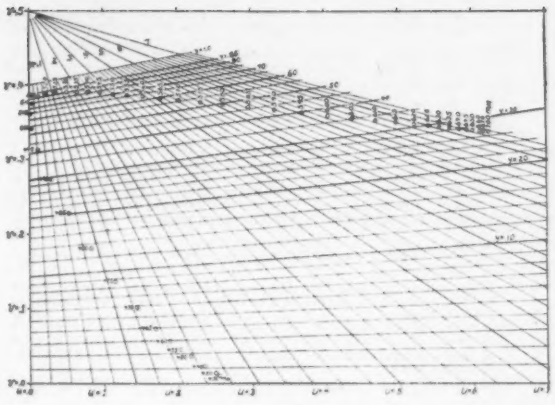

FIG. 5

**MacAdam's U.C.S. Transformation (Equation 3) of I.C.I. Coordinate System.**

Scofield *(43)*, working with Hunter and Judd, in 1940 proposed to the A.S.T.M. Committee D-1 a uniform chromaticity chart based originally on Judd's U.C.S. data but with gray placed at the origin of the coordinates. This was followed by two other papers *(44, 45)*. In the first, formulas were given for transforming I.C.I. data to $(\alpha, \beta)$-data that plot as shown in Fig. 8. The method specifies color by three numbers, one to indicate luminous apparent reflectance $A\theta_1\theta_V$, or luminous transmittance $T$, the others to represent chromaticity, $\alpha$ and $\beta$. These are related to the I.C.I. systems by the following equations:

$$\alpha = \frac{2.4266x - 1.3631y - 0.3214}{1.0000x + 2.2633y + 1.1054}$$
$$\beta = \frac{0.5710x + 1.2447y - 0.5708}{1.0000x + 2.2633y + 1.1054} \quad (7)$$

Three advantages are pointed out for use of this system, first that it yields fairly uniform chromaticity scales, second that it uses rectangular coordinates with the origin at the neutral point, and third—and probably most useful to the paint industry—the speed with which values of $\alpha$ and $\beta$ may be determined on photoelectric tristimulus colorimeters used in the paint industry. Readings obtained on these instruments are quickly converted to the coordinates of this system. By use of the Hunter Multipurpose Reflectometer, for which the $(\alpha, \beta)$-system was originally chosen, the readings obtained through the amber, green, and blue filters (A, G, and B) of that instrument may be directly converted by the following formulas:

$$\alpha = \frac{A - G}{A + 2G + B}$$
$$\beta = \frac{0.4(G - B)}{A + 2G + B} \quad (8)$$

There are limitations in using results of photoelectric instruments in this manner, but they are quite

TABLE I.—MUNSELL RE-NOTATIONS FOR MATTE SIDES OF CHIPS FOR HUES 1 TO 24 IN THE COLOR HARMONY MANUAL[1]

| Ostwald Notation | Hue 1 | Hue 2 | Hue 3 | Hue 4 | Hue 5 | Hue 6 | Hue 7 | Hue 8 | Hue 9 | Hue 10 | Hue 11 | Hue 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pa | 7 Y 8.8/13.0 | 3.5 Y 8.6/14.0 | 8.5YR 7.6/13.9 | 5 YR 7.0/13.6 | 1.5YR 6.2/13.9 | 9 R 5.5/14.7 | 6.5 R 4.2/12.0 | 0.5 R 3.8/10.0 | 5 RP 3.7/ 8.5 | 0.5RP 3.6/ 7.1 | 6 P 3.6/ 6.5 | 2.5 P 3.5/ 7.1 |
| na | 7.5 Y 9.0/11.8 | 3.5 Y 8.6/13.5 | 8.5YR 7.6/12.6 | 4 YR 7.0/12.6 | 1.5YR 6.4/12.8 | 7.5 R 5.6/13.4 | 5 R 4.3/10.7 | 0.5 R 4.4/10.0 | 5.5RP 4.2/ 9.5 | 0.5RP 4.0/ 7.9 | 5.5 P 4.0/ 7.4 | 2.5 P 3.9/ 7.4 |
| pc | 8 Y 7.3/10.2 | 5 Y 7.2/10.7 | 10 YR 6.5/10.4 | 5 YR 6.2/11.5 | 2 YR 5.4/11.2 | 8.5 R 4.7/11.2 | 5.5 R 3.6/ 9.2 | 1 R 3.2/ 7.4 | 4.5RP 3.2/ 6.4 | 1 RP 3.3/ 6.6 | 6 P 3.1/ 5.2 | 1.5 P 2.9/ 4.7 |
| la | 7 Y 9.0/10.8 | 3.5 Y 8.7/11.8 | 8.5YR 7.6/11.3 | 4 YR 7.1/11.3 | 0.5YR 6.4/11.6 | 7.5 R 5.9/12.3 | 5 R 4.8/ 9.1 | 10 RP 4.8/ 9.6 | 4.5RP 4.8/ 9.7 | 0.5RP 4.7/ 8.4 | 6 P 4.4/ 7.5 | 2.5 P 4.4/ 7.4 |
| nc | 8 Y 7.2/ 8.9 | 3.5 Y 7.2/10.0 | 9.5YR 6.3/ 9.3 | 5 YR 6.0/ 9.7 | 1.5YR 5.5/ 9.9 | 7.5 R 4.9/ 9.5 | 4.5 R 3.8/ 7.9 | 0.5 R 3.7/ 6.5 | 5 RP 3.8/ 7.5 | 1 RP 3.6/ 6.7 | 5.5 P 3.4/ 5.9 | 1.5 P 3.4/ 5.9 |
| pe | 8 Y 6.2/ 8.2 | 5 Y 6.2/ 8.5 | 1.5 Y 5.5/ 7.4 | 6.5YR 5.3/ 8.0 | 2.5YR 4.7/ 8.6 | 8 R 4.2/ 9.8 | 5.5 R 3.1/ 6.0 | 0.5 R 3.0/ 5.2 | 4.5RP 2.9/ 4.5 | 1 RP 2.9/ 5.1 | 5 P 2.7/ 3.4 | 1.5 P 2.7/ 3.9 |
| ia | 7.5 Y 9.1/ 9.2 | 3 Y 8.6/10.2 | 8.5YR 7.9/ 9.5 | 4 YR 7.4/ 9.8 | 10 R 6.9/10.3 | 7 R 6.4/ 9.8 | 3.5 R 5.5/ 8.0 | 10 RP 5.2/ 9.3 | 4 RP 5.6/ 9.3 | 10 P 5.3/ 8.6 | 5 P 5.0/ 7.7 | 3 P 5.0/ 7.8 |
| ic | 7.5 Y 7.1/ 7.8 | 3.5 Y 7.2/ 8.6 | 8 YR 6.6/ 8.0 | 5 YR 6.1/ 7.7 | 0.5YR 5.6/ 8.7 | 6 R 5.3/ 9.4 | 4 R 4.2/ 6.8 | 0.5 R 4.2/ 7.4 | 4.5RP 4.3/ 7.0 | 10 P 4.2/ 6.6 | 5 P 3.8/ 6.0 | 2 P 3.8/ 6.0 |
| ne | 9 Y 6.0/ 6.9 | 5 Y 6.1/ 7.2 | 10 YR 5.5/ 6.6 | 5 YR 5.3/ 6.9 | 0.5YR 4.6/ 7.4 | 7 R 4.1/ 7.9 | 4.5 R 3.5/ 5.9 | 0.5 R 3.4/ 5.4 | 4.5RP 3.5/ 5.0 | 9.5 P 3.2/ 4.4 | 5 P 3.2/ 4.1 | 1.5 P 3.0/ 3.8 |
| pg | 9 Y 5.2/ 6.2 | 6 Y 5.4/ 6.4 | 1 Y 4.8/ 6.0 | 6.5YR 4.6/ 6.0 | 2 YR 4.0/ 6.3 | 7 R 3.5/ 6.7 | 6.5 R 2.8/ 4.0 | 1 R 2.8/ 4.1 | 3.5RP 2.7/ 4.0 | 9.5 P 2.6/ 3.4 | 4.5 P 2.5/ 2.2 | 10 PB 2.5/ 2.9 |
| ga | 7.5 Y 9.1/ 7.8 | 2.5 Y 8.6/ 8.2 | 7.5YR 8.2/ 7.2 | 4 YR 7.8/ 7.5 | 9.5 R 7.3/ 7.4 | 5 R 6.9/ 8.3 | 2.5 R 6.4/ 7.3 | 9 RP 6.0/ 8.0 | 3.5RP 6.3/ 8.4 | 9.5 P 6.2/ 8.0 | 5 P 5.6/ 7.4 | 3 P 5.6/ 7.5 |
| ic | 7.5 Y 7.2/ 6.7 | 3.5 Y 7.4/ 7.2 | 5.5YR 6.8/ 7.0 | 4.5YR 6.5/ 6.6 | 9.5 R 5.9/ 7.2 | 5 R 5.5/ 6.8 | 3 R 5.2/ 6.1 | 8.5RP 4.7/ 6.1 | 2.5RP 5.1/ 6.9 | 9 P 4.8/ 5.8 | 3.5 P 4.5/ 5.8 | 2 P 4.4/ 6.2 |
| le | 8 Y 6.1/ 5.9 | 4 Y 6.1/ 5.7 | 8.5YR 5.6/ 5.3 | 4 YR 5.3/ 5.8 | 10 R 4.9/ 6.2 | 5 R 4.5/ 5.2 | 3.5 R 4.4/ 4.1 | 9.5RP 3.9/ 4.8 | 2.5RP 4.1/ 4.7 | 8 P 3.8/ 4.0 | 4.5 P 3.6/ 4.6 | 2 P 3.6/ 4.2 |
| ng | 8 Y 5.1/ 4.8 | 4 Y 5.2/ 5.1 | 8 YR 4.8/ 4.5 | 5 YR 4.5/ 4.8 | 0.5YR 4.1/ 5.4 | 6 R 3.7/ 4.8 | 4 R 3.3/ 3.6 | 10 RP 3.2/ 3.2 | 3 RP 3.2/ 3.0 | 7.5 P 3.0/ 2.7 | 4.5 P 2.9/ 2.5 | 0.5 P 2.9/ 2.7 |
| pi | 8.5 Y 4.6/ 4.6 | 5 Y 4.5/ 4.8 | 1 Y 4.2/ 4.4 | 6.5YR 4.0/ 4.3 | 1.5YR 3.5/ 4.6 | 8 R 3.1/ 4.2 | 6.5 R 2.6/ 3.2 | 1 R 2.6/ 3.0 | 2 RP 2.5/ 1.8 | 7 P 2.4/ 1.8 | 4 P 2.4/ 1.7 | 10 PB 2.4/ 1.8 |
| ea | 7 Y 9.2/ 5.6 | 2 Y 8.9/ 5.4 | 7 YR 8.5/ 5.0 | 2.5YR 8.2/ 5.1 | 9.5 R 8.0/ 5.8 | 5 R 7.6/ 6.4 | 2 R 7.3/ 5.4 | 6.5RP 7.3/ 5.9 | 2 RP 7.5/ 6.2 | 7.5 P 7.2/ 6.1 | 4.5 P 6.6/ 6.4 | 2 P 6.4/ 6.5 |
| gc | 7.5 Y 7.3/ 4.8 | 2.5 Y 7.4/ 4.6 | 7.5YR 6.9/ 4.3 | 3 YR 6.5/ 4.3 | 9 R 6.5/ 5.4 | 5 R 6.2/ 5.5 | 2.5 R 6.1/ 4.2 | 6 RP 6.0/ 4.4 | 2.5RP 5.8/ 4.7 | 8 P 5.5/ 5.0 | 4 P 5.2/ 6.3 | 2.5 P 4.9/ 5.7 |
| ie | 8.5 Y 6.1/ 4.1 | 2.5 Y 6.1/ 3.6 | 7.5YR 5.8/ 3.8 | 4 YR 5.6/ 4.0 | 10 R 5.3/ 4.8 | 5 R 5.0/ 4.5 | 1 R 4.8/ 3.4 | 6 RP 4.8/ 3.9 | 1.5RP 4.7/ 3.7 | 8 P 4.4/ 3.8 | 4 P 4.1/ 4.1 | 2 P 3.9/ 3.7 |
| ig | 8 Y 5.0/ 3.6 | 3.5 Y 5.1/ 3.1 | 7 YR 4.8/ 3.3 | 3.5YR 4.7/ 3.6 | 10 R 4.3/ 3.8 | 5 R 4.2/ 3.4 | 2.5 R 4.0/ 2.3 | 6.5RP 3.7/ 3.0 | 2 RP 3.8/ 2.6 | 7.5 P 3.7/ 2.8 | 3 P 3.3/ 2.5 | 0.5 P 3.3/ 2.6 |
| ni | 9 Y 4.3/ 3.5 | 4 Y 4.2/ 2.5 | 9.5YR 4.2/ 3.0 | 4.5YR 3.9/ 3.5 | 10 R 3.6/ 3.0 | 5 R 3.3/ 2.9 | 4.5 R 3.2/ 2.0 | 6 RP 3.0/ 1.9 | 2 RP 3.1/ 1.5 | 7.5 P 3.0/ 1.8 | 3 P 2.8/ 1.6 | 10 PB 2.7/ 1.8 |
| pl | 8.5 Y 3.9/ 3.4 | 4 Y 3.7/ 2.7 | 0.5 Y 3.6/ 3.1 | 6 YR 3.5/ 2.9 | 1.5YR 3.0/ 3.0 | 7 R 2.8/ 2.8 | 5.5 R 2.5/ 1.5 | 9 RP 2.5/ 1.7 | 2 RP 2.4/ 1.0 | 5 P 2.2/ 1.0 | 2 P 2.3/ 1.3 | 9.5PB 2.2/ 1.2 |
| ca | 7.5 Y 9.4/ 3.3 | 2 Y 9.1/ 2.8 | 5.5YR 8.9/ 3.0 | 2 YR 8.8/ 3.0 | 7.5 R 8.6/ 3.8 | 2.5 R 8.5/ 3.7 | 0.5 R 8.4/ 3.0 | 6.5RP 8.8/ 2.9 | 3 RP 8.4/ 4.2 | 8.5 P 8.2/ 4.3 | 5.5 P 7.6/ 5.1 | 2.5 P 7.3/ 5.3 |
| ec | 8.5 Y 7.5/ 2.6 | 2.5 Y 7.6/ 2.7 | 7 YR 7.2/ 2.4 | 2.5YR 7.2/ 2.9 | 7.5 R 7.4/ 2.9 | 2 R 7.1/ 3.3 | 7 RP 7.0/ 2.6 | 3.5RP 7.8/ 2.8 | 2.5RP 6.9/ 3.8 | 8.5 P 6.6/ 4.2 | 5 P 5.9/ 5.2 | 2.5 P 5.5/ 4.2 |
| ge | 9.5 Y 6.2/ 2.2 | 4.5 Y 6.4/ 2.4 | 6.5YR 5.8/ 2.2 | 2.5YR 6.0/ 2.3 | 7.5 R 5.6/ 2.5 | 0.5 R 5.6/ 1.5 | 7 RP 5.6/ 2.3 | 4.5RP 5.8/ 2.0 | 3 RP 5.6/ 3.2 | 7.5 P 5.3/ 3.2 | 5 P 4.9/ 3.6 | 1.5 P 4.6/ 3.6 |
| ig | 8.5 Y 5.1/ 1.9 | 3.5 Y 5.2/ 2.2 | 7 YR 4.8/ 1.7 | 2.5YR 4.9/ 1.9 | 8.5 R 4.7/ 2.2 | 2 R 4.5/ 2.3 | 5 RP 4.5/ 1.3 | 4 RP 4.6/ 1.6 | 3 RP 4.4/ 1.9 | 6 P 4.4/ 2.3 | 5 P 4.0/ 2.2 | 0.5 P 3.8/ 2.4 |
| li | 9.5 Y 4.3/ 1.7 | 3.5 Y 4.4/ 1.9 | 8.5YR 4.2/ 1.6 | 3.5YR 4.0/ 1.7 | 9.5 R 4.0/ 1.6 | 2.5 R 3.8/ 1.9 | 7.5RP 3.8/ 1.1 | 3.5RP 3.9/ 1.2 | 2.5RP 3.6/ 1.4 | 5.5 P 3.5/ 1.6 | 4 P 3.5/ 1.7 | 9.5PB 3.2/ 1.8 |
| nl | 9 Y 3.8/ 1.8 | 2.5 Y 3.7/ 1.5 | 10 YR 3.4/ 1.4 | 4.5YR 3.4/ 1.6 | 10 R 3.3/ 1.8 | 2.5 R 3.2/ 1.6 | 8.5RP 3.0/ 0.7 | 3 RP 3.1/ 0.8 | 2.5RP 2.8/ 0.8 | 6 P 2.8/ 0.9 | 2.5 P 2.8/ 1.2 | 8 PB 2.7/ 1.1 |
| pn | 9 Y 3.2/ 2.2 | 3.5 Y 3.0/ 1.7 | 0.5 Y 2.9/ 1.6 | 4.5YR 3.0/ 1.6 | 0.5YR 2.6/ 1.7 | 4.5 R 2.5/ 1.3 | 7 R 2.3/ 0.5 | 7.5RP 2.4/ 0.9 | 9.5 P 2.2/ 0.6 | 9 P 2.2/ 0.4 | 2 P 2.2/ 0.7 | 7.5PB 2.2/ 0.4 |

TABLE I.—*Continued*

| Ostwald Notation | Hue 13 | Hue 14 | Hue 15 | Hue 16 | Hue 17 | Hue 18 | Hue 19 | Hue 20 | Hue 21 | Hue 22 | Hue 23 | Hue 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pa | 7.5PB 3.6/12.8 | 5 PB 3.5/ 8.7 | 10 B 3.8/ 6.6 | 5 B 4.0/ 5.9 | 1 B 4.1/ 5.8 | 8 BG 4.3/ 6.2 | 5 BG 4.5/ 6.4 | 3.5BG 4.6/ 6.9 | 9 G 5.0/ 7.4 | 3 G 5.3/ 8.6 | 9.5GY 6.1/11.3 | 6 GY 7.6/11.7 |
| na | 7.5PB 4.0/12.4 | 5 PB 4.0/ 9.4 | 0.5PB 4.3/ 7.8 | 5 B 4.5/ 6.7 | 9.5BG 4.8/ 6.8 | 8.5BG 4.8/ 6.8 | 5 BG 5.0/ 7.2 | 3.5BG 5.2/ 7.4 | 10 G 5.4/ 7.3 | 3.5 G 5.6/ 8.4 | 10 GY 6.2/10.1 | 6.5GY 7.6/10.6 |
| pc | 7.5PB 3.2/10.1 | 5 PB 3.2/ 7.0 | 8.5 B 3.5/ 5.1 | 5 B 3.7/ 5.4 | 9.5BG 3.8/ 5.4 | 8 BG 3.8/ 5.3 | 4 BG 3.9/ 5.7 | 3.5BG 4.0/ 6.0 | 9 G 4.2/ 6.3 | 3 G 4.6/ 7.9 | 10 GY 5.4/ 9.6 | 6 GY 6.4/ 9.3 |
| la | 7.5PB 4.2/10.7 | 5 PB 4.5/ 9.6 | 0.5PB 4.8/ 8.5 | 5.5 B 5.1/ 7.0 | 2 B 5.2/ 6.9 | 9 BG 5.2/ 6.7 | 5 BG 5.5/ 7.3 | 4 BG 5.9/ 7.5 | 10 G 5.9/ 7.8 | 4.5 G 5.9/ 8.1 | 0.5 G 6.6/ 9.6 | 6 GY 7.8/ 9.8 |
| nc | 7.5PB 3.4/10.3 | 5 PB 3.5/ 7.1 | 10 B 3.9/ 6.5 | 5 B 4.0/ 5.5 | 2.5 B 4.1/ 5.4 | 10 BG 4.1/ 5.4 | 4 BG 4.3/ 5.8 | 4 BG 4.6/ 6.2 | 9.5 G 4.5/ 6.2 | 4 G 4.8/ 7.3 | 10 GY 5.5/ 8.9 | 6 GY 6.6/ 8.8 |
| pe | 7.5PB 2.6/ 7.6 | 5 PB 2.8/ 5.4 | 9 B 3.1/ 4.2 | 4 B 3.4/ 4.5 | 1 B 3.3/ 4.0 | 7.5BG 3.4/ 4.3 | 3.5BG 3.3/ 5.1 | 3.5BG 3.6/ 4.7 | 8.5 G 3.7/ 5.3 | 3 G 4.1/ 6.8 | 10 GY 4.8/ 7.9 | 6.5GY 5.7/ 8.0 |
| ia | 8 PB 4.8/ 9.7 | 5 PB 5.4/ 9.0 | 0.5PB 5.7/ 8.4 | 6.5 B 5.9/ 7.1 | 3.5 B 5.9/ 6.7 | 10 BG 5.8/ 6.6 | 6 BG 6.4/ 6.6 | 5 BG 6.4/ 7.2 | 10 G 6.5/ 7.4 | 5 G 6.5/ 7.7 | 0.5 G 7.1/ 8.7 | 7 GY 8.0/ 8.9 |
| ic | 8 PB 3.9/ 9.5 | 5 PB 4.2/ 7.3 | 10 B 4.4/ 6.9 | 7.5 B 4.7/ 6.2 | 4.5 B 4.6/ 6.0 | 9.5BG 4.5/ 5.5 | 6.5BG 5.0/ 5.6 | 4.5BG 5.1/ 6.2 | 0.5BG 5.1/ 6.2 | 4 G 5.3/ 7.3 | 0.5 G 5.7/ 7.6 | 6.5GY 6.7/ 7.9 |
| ne | 8 PB 3.0/ 7.5 | 4.5PB 3.3/ 5.5 | 9.5 B 3.5/ 4.8 | 7 B 3.8/ 4.6 | 3.5 B 3.7/ 4.5 | 0.5 B 3.7/ 4.6 | 3.5BG 3.9/ 4.3 | 4 BG 4.0/ 4.4 | 9 G 4.1/ 5.0 | 3.5 G 4.3/ 6.2 | 1 G 5.0/ 7.6 | 6 GY 5.6/ 6.8 |
| pg | 7 PB 2.4/ 4.1 | 5 PB 2.6/ 3.6 | 9 B 2.8/ 2.9 | 5.5 B 3.0/ 3.4 | 10 BG 3.0/ 3.2 | 6 BG 3.0/ 3.5 | 3.5BG 2.9/ 3.9 | 4.5BG 3.4/ 3.5 | 8.5 G 3.4/ 4.4 | 3 G 3.7/ 5.8 | 10 GY 4.3/ 6.5 | 6.5GY 5.0/ 6.3 |
| ga | 8.5PB 5.8/ 8.5 | 5 PB 6.3/ 7.9 | 1.5PB 6.8/ 7.5 | 7.5 B 6.8/ 6.3 | 3.5 B 7.0/ 5.8 | 1 B 7.0/ 5.7 | 7 BG 7.4/ 5.8 | 4 BG 7.2/ 6.2 | 1.5BG 7.2/ 6.3 | 5.5 G 7.4/ 6.5 | 1 G 7.6/ 7.5 | 7 GY 8.4/ 7.1 |
| ic | 8 PB 4.7/ 7.5 | 5 PB 4.9/ 6.2 | 0.5PB 5.1/ 6.7 | 7.5 B 5.3/ 5.4 | 3 B 5.1/ 5.1 | 1 B 5.5/ 4.8 | 7.5BG 5.7/ 4.5 | 5 BG 5.8/ 5.7 | 2.5BG 5.7/ 5.5 | 5 G 6.0/ 6.2 | 1 G 6.2/ 7.0 | 6.5GY 6.8/ 6.2 |
| le | 8 PB 3.7/ 6.2 | 4.5PB 3.9/ 5.4 | 10 B 4.1/ 5.4 | 8.5 B 4.2/ 4.4 | 3 B 4.3/ 4.5 | 10 BG 4.4/ 4.2 | 5.5BG 4.5/ 4.0 | 4 BG 4.7/ 4.6 | 10 G 4.7/ 4.7 | 5 G 4.9/ 5.1 | 1 G 5.3/ 6.2 | 7 GY 5.8/ 5.6 |
| ng | 7.5PB 2.8/ 4.8 | 4 PB 2.9/ 4.0 | 10 B 3.3/ 3.5 | 7.5 B 3.4/ 3.0 | 0.5 B 3.4/ 2.9 | 10 BG 3.4/ 3.2 | 5 BG 3.6/ 3.1 | 3.5BG 3.8/ 3.1 | 0.5BG 3.8/ 3.9 | 3 G 4.0/ 4.5 | 0.5 G 4.5/ 5.5 | 6.5GY 5.0/ 5.6 |
| pi | 7.5PB 2.3/ 3.1 | 3.5PB 2.5/ 1.9 | 8.5 B 2.6/ 2.0 | 6.5 B 2.7/ 2.3 | 3 B 2.8/ 2.6 | 7.5BG 2.7/ 2.4 | 5.5BG 2.7/ 2.8 | 4.5BG 3.0/ 2.4 | 8.5 G 3.1/ 3.4 | 2.5 G 3.4/ 4.3 | 0.5 G 3.8/ 4.7 | 6 GY 4.3/ 4.8 |
| ea | 8.5PB 7.1/ 6.0 | 5 PB 7.4/ 5.7 | 1.5PB 7.8/ 5.4 | 8 B 7.9/ 4.6 | 3.5 B 7.9/ 4.5 | 2.5 B 7.8/ 4.3 | 9.5BG 7.9/ 4.3 | 4.5BG 8.1/ 4.8 | 2.5BG 8.1/ 4.8 | 7 G 8.2/ 4.7 | 2 G 8.2/ 5.3 | 8 GY 8.7/ 5.1 |
| gc | 9 PB 5.6/ 5.7 | 5 PB 5.9/ 5.4 | 10 B 6.1/ 5.1 | 7.5 B 6.2/ 4.7 | 6 B 5.9/ 4.7 | 0.5 B 6.1/ 4.0 | 7.5BG 6.3/ 3.9 | 4.5BG 6.4/ 4.5 | 1.5BG 6.4/ 3.9 | 6.5 G 6.6/ 4.7 | 1.5 G 6.9/ 4.9 | 7.5GY 7.0/ 5.0 |
| ie | 8 PB 4.5/ 5.6 | 4 PB 4.7/ 4.4 | 0.5PB 4.7/ 4.2 | 8 B 5.0/ 4.0 | 5 B 4.8/ 3.8 | 2 B 5.0/ 3.3 | 7.5BG 5.1/ 3.2 | 4 BG 5.2/ 3.7 | 1 BG 5.4/ 3.7 | 6 G 5.5/ 3.8 | 1.5 G 5.5/ 4.3 | 7.5GY 5.6/ 4.3 |
| ig | 7.5PB 3.6/ 4.5 | 6 PB 3.5/ 3.5 | 10 B 3.9/ 3.1 | 7.5 B 4.0/ 3.2 | 5 B 3.8/ 2.7 | 10 BG 4.0/ 2.5 | 6 BG 3.9/ 2.6 | 3.5BG 4.3/ 3.0 | 10 G 4.3/ 3.2 | 4.5 G 4.4/ 3.4 | 1.5 G 4.7/ 3.7 | 7 GY 4.7/ 3.7 |
| ni | 7.5PB 2.8/ 3.3 | 4.5PB 2.8/ 2.0 | 10 B 3.1/ 1.8 | 8 B 3.2/ 2.0 | 2.5 B 3.3/ 2.1 | 8 BG 3.2/ 1.7 | 6 BG 3.3/ 2.1 | 4 BG 3.6/ 2.2 | 0.5BG 3.5/ 2.7 | 4.5 G 3.8/ 2.7 | 1 G 3.9/ 3.3 | 6 GY 4.1/ 3.5 |
| pl | 5.5PB 2.1/ 1.6 | 7 PB 2.3/ 1.2 | 6.5 B 2.5/ 1.4 | 4 B 2.5/ 1.3 | 3 B 2.6/ 1.5 | 9.5BG 2.5/ 1.4 | 7.5BG 2.5/ 1.6 | 4.5BG 2.9/ 1.9 | 9.5 G 2.9/ 2.4 | 3.5 G 3.1/ 2.8 | 10 GY 3.3/ 3.2 | 6 GY 3.6/ 3.2 |
| ca | 9.5PB 7.9/ 4.3 | 5 PB 8.0/ 3.9 | 2.5PB 8.6/ 3.5 | 8.5 B 8.5/ 3.3 | 6 B 8.6/ 2.9 | 4 B 8.5/ 3.0 | 2 B 8.4/ 2.9 | 4.5BG 8.9/ 2.3 | 10 G 9.0/ 2.5 | 6.5 G 8.9/ 2.8 | 2.5 G 8.9/ 2.8 | 8 GY 9.0/ 2.4 |
| ec | 9 PB 5.9/ 3.6 | 5.5PB 6.5/ 3.9 | 0.5PB 7.2/ 3.0 | 7.5 B 7.1/ 3.5 | 7.5 B 7.0/ 3.0 | 5 B 7.0/ 2.9 | 1 B 6.8/ 2.7 | 6 BG 7.2/ 2.6 | 2.5BG 7.2/ 2.8 | 6 G 7.3/ 3.0 | 2.5 G 7.3/ 2.9 | 8 GY 7.7/ 2.7 |
| ge | 8.5PB 4.9/ 3.2 | 5 PB 5.6/ 3.0 | 1.5PB 5.5/ 2.7 | 8.5 B 5.7/ 3.0 | 5.5 B 5.4/ 2.7 | 0.5 B 5.5/ 2.0 | 2 B 5.5/ 2.4 | 5 BG 5.9/ 2.0 | 2.5BG 5.9/ 2.0 | 6 G 6.1/ 2.8 | 2 G 5.9/ 2.2 | 8.5GY 6.2/ 2.2 |
| ig | 8 PB 4.2/ 2.6 | 5 PB 4.3/ 2.0 | 0.5PB 4.4/ 2.0 | 8 B 4.6/ 2.2 | 6.5 B 4.5/ 2.1 | 1.5 B 4.5/ 1.5 | 10 BG 4.6/ 1.9 | 4 BG 4.8/ 1.6 | 2 BG 4.9/ 2.0 | 5 G 4.9/ 2.3 | 2 G 4.9/ 2.1 | 7.5GY 5.1/ 2.0 |
| li | 7.5PB 3.3/ 1.9 | 3.5PB 3.3/ 1.5 | 10 B 3.7/ 1.4 | 6.5 B 3.8/ 1.5 | 7.5 B 4.0/ 1.8 | 2.5 B 3.7/ 1.4 | 0.5 B 3.8/ 1.6 | 5 BG 4.0/ 1.2 | 2 BG 4.1/ 1.8 | 5.5 G 4.1/ 2.0 | 2 G 4.1/ 1.8 | 7 GY 4.3/ 1.9 |
| nl | 6.5PB 2.7/ 1.6 | 4.5PB 2.8/ 1.0 | 10 B 2.9/ 0.8 | 5.5 B 3.1/ 1.1 | 7.5 B 3.1/ 1.1 | 4.5BG 3.0/ 1.2 | 8.5BG 3.0/ 1.3 | 2.5BG 3.3/ 1.2 | 9.5 G 3.3/ 1.3 | 3 G 3.3/ 1.8 | 10 GY 3.5/ 1.8 | 6.5GY 3.5/ 1.6 |
| pn | 5.5PB 2.1/ 1.3 | 7 PB 2.3/ 0.7 | 4 PB 2.4/ 1.0 | 10 BG 2.4/ 0.6 | 8.5BG 2.6/ 1.0 | 4.5BG 2.4/ 1.2 | 9.5BG 2.4/ 1.1 | 5 BG 2.7/ 1.0 | 1 BG 2.7/ 1.2 | 2.5 G 2.8/ 1.8 | 10 GY 2.9/ 1.8 | 6.5GY 3.0/ 1.9 |

[1] Data converted from chip specifications *(12)* by using recommendations in Munsell report *(31)*. Ostwald hues 1 to 12 are listed in the top of the table, with complementary hues 13 to 24, directly below.

fully discussed both in the Scofield and Hunter papers *(15)*.

For further simplification for use with the Hunter instrument the following modification is suggested by Scofield *(44)* in his later paper:

$$\begin{matrix} L = 100 \times \sqrt{\text{Reflectance}} \\ A = 7La \\ B = 7L\beta \end{matrix} \qquad (9)$$

In 1940 Adams *(2)* in discussing different forms of the Maxwell triangle used in colorimetry, suggested that since $Y$ is the unique coordinate to which all the luminosity of the I.C.I. system is attached, a plot of $z$ against $x$ might seem more logical than the usual $y$ against $x$. Such a diagram, including the spectrum and black body loci, is shown in Fig. 9. Dr. Adams points out that the equal energy stimulus, used in all usual I.C.I. diagrams, is but one of the five unique chromaticities and perhaps not even the most significant of the five.

Adams describes three methods of plotting I.C.I. data to provide a nearly uniform radial and circumferential spacing of the Munsell colors centered about the neutral color of equal value. One of these he calls a chromance diagram. On it the illuminant is the central point (for $C$ illuminant, $X_c=Y_c=Z_c$, not $X_c = 1.01998X$, $Y_c = Y$, $Z_c = 0.84672Z$), hence the neutral colors lie at the origin of coordinates, and when plotted $X_c$ minus $Y_c$ against $Z_c$ minus $Y_c$ for colors of equal Munsell value, the distance along any radius is proportional to colorimetric purity. Figure 10 shows such a chromance plot for colors of Munsell value 5/.

The Maxwell triangle and its rectangular equivalents are chromaticity diagrams but not the only ones that can be based upon the I.C.I. system. For example, the ratios $X_c/Y_c$ and $Z_c/Y_c$ depend only on the

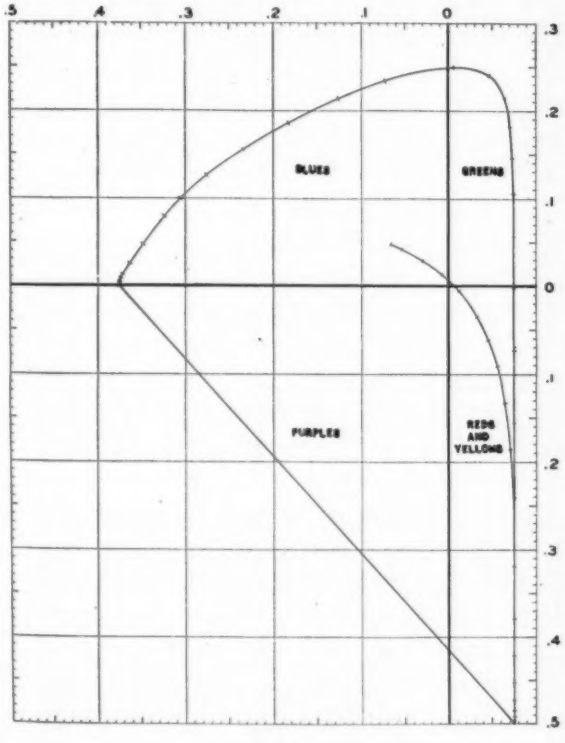


FIG. 6

**Breckenridge and Schaub R.U.C.S. Diagram. The Spectrum and Planckian Loci Are Indicated. The Equal Energy Point Is at the 0 Point of the Coordinate System. Quadrant 1 Contains Greens, 2 the Blues, 3 the Purples, and 4 Reds and Yellows.**

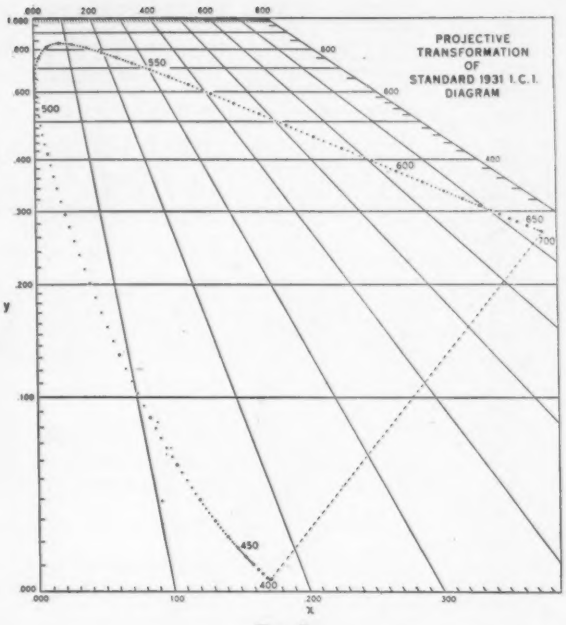


FIG. 7

**Farnsworth Projective Transformation of Standard I.C.I. Diagram Set up so That Munsell 5/5 Colors Show a Minimum Deviation from Circularity.**

chromaticity of the sample. A plot of these two ratios may therefore be referred to as a "constant brightness chromaticity diagram." For samples of Munsell 5/ value, such a plot is shown in Fig. 11. This is geometrically similar to Fig. 10, but the ratios of the two diagrams will differ for colors of different value. For plotting chromaticity of light sources the data are referred to equal energy, and $Z/Y$ plotted against $X/Y$. A portion of the spectrum and black body locus, plus a number of fluorescent lamps, is shown plotted in Fig. 12, Adams' second proposal.

Adams' third diagram, one found most useful by the writer, and employed during the study of developing smoothed loci on the I.C.I. $(x, y)$-diagram for Munsell hue and chroma *(31)*, has been called by Dr. Adams the chromatic-value diagram. By applying the Munsell value function $(V)$ to all three components of reflectance ($px \equiv X_c$, $py \equiv Y_c$, $pz \equiv Z_c$) the resulting $V_X$, $V_Y$, $V_Z$ will uniquely define any color. The differences, $V_X - V_Y$ and $V_Z - V_Y$ will be zero for an achromatic color. These subtractions are described as the mathematical representation of postulations made in the Adams' theory of color vision *(1)*. Figure 13 shows a chromatic value plot ($V_X - V_Y$ against $V_Z - V_Y$) for Munsell re-notations at value 5/, extrapolated to the MacAdam limit in accord with the recommendations of Newhall, Nickerson, and Judd *(31)*. While lines of constant chroma are not circles on this diagram, they do come out in a more regular fashion, when extrapolated to limit chromas, than on any other diagram proposed up to 1942. The conversion is very simple, there are no difficult or time-consuming equations to be solved. By use of Munsell value equivalents for I.C.I. $Y$ $(V_Y)$ as given in Table II, page 406, 1943 Journal of the Optical Society of America *(31)*, and two similar tables for $V_X$ and $V_Z$ in which $V=10$ for $V_X$ is adjusted for 0.9804, and $V_Z$ for 1.1810, the three figures for $V_X$, $V_Y$, and $V_Z$ may be read directly* from I.C.I. $(X, Y, Z)$-data. The

* Tables for $V_X$, $V_Y$, $V_Z$ have been prepared by the author and are available on request.

TABLE II.—COLOR CONVERSION OF SAMPLES IN PLATES 1-20, MAERZ AND PAUL DICTIONARY OF COLOR, TO MUNSELL NOTATION. (CONVERTED BY DIRECT VISUAL COMPARISON ACCORDING TO THE KELLY MASK METHOD, TO SAMPLES IN THE MUNSELL *BOOK OF COLOR*. COLUMN AND LINE DESIGNATION FOR EACH MAERZ AND PAUL PLATE IS INDICATED BY LETTER AND NUMBER)

| No. | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | MAERZ AND PAUL—PLATE 1 | | | | | | | |
| 1 | 5 Y 9.2/ 0.2 | 2.5 R 9.0/ 2.0 | 2 R 8.5/ 3.0 | 2 R 8.1/ 4.0 | 2 R 7.8/ 6.0 | 2 R 7.5/ 6.0 | 2 R 7.0/ 7.0 | 2 R 7.0/ 8.0 | 2.5 R 6.7/ 8.5 | 2.5 R 6.1/10.0 | 3.5 R 5.9/10.0 | 4 R 5.0/12.0 |
| 2 | 5 R 8.5/ 2.0 | 4 R 8.0/ 4.0 | 3 R 7.8/ 7.0 | 2.5 R 7.7/ 6.0 | 2 R 7.3/ 7.0 | 2 R 7.2/ 8.0 | 2 R 7.0/ 9.0 | 2 R 7.1/ 9.0 | 2 R 6.8/10.0 | 2.5 R 6.2/12.0 | 3 R 5.7/10.0 | 4 R 5.0/14.0 |
| 3 | 10 RP 8.2/ 7.0 | 10 RP 7.5/ 7.0 | 10 RP 7.4/ 7.5 | 1 R 7.2/ 8.0 | 1 R 7.0/ 9.0 | 1 R 7.0/10.0 | 1 R 6.5/10.0 | 1 R 6.5/10.0 | 1 R 6.0/10.0 | 2 R 5.5/10.0 | 3 R 5.2/12.0 | 4 R 4.8/15.0 |
| 4 | 8 RP 7.0/10.0 | 9 RP 6.5/10.0 | 8.5RP 6.4/10.0 | 9 RP 6.2/11.0 | 9 RP 6.1/11.0 | 9 RP 5.9/11.0 | 10 RP 5.8/11.0 | 10 RP 5.7/11.5 | 10 RP 5.4/12.0 | 1 R 5.2/12.0 | 3 R 5.0/13.0 | 4 R 4.3/16.0 |
| 5 | 8 RP 6.2/12.0 | 9 RP 6.0/12.0 | 10 RP 6.0/12.0 | 10 RP 6.0/13.0 | 10 RP 6.0/14.0 | 10 RP 6.0/15.0 | 10 RP 5.5/14.0 | 10 RP 5.0/14.0 | 1 R 5.0/14.0 | 2 R 4.8/14.0 | 3 R 4.7/14.0 | 4 R 4.5/16.0 |
| 6 | 8 RP 5.0/14.0 | 10 RP 4.8/12.0 | 10 RP 4.8/12.0 | 10 RP 4.8/12.0 | 10 RP 4.7/12.0 | 10 RP 4.7/12.0 | 1 R 4.5/12.0 | 2 R 4.5/12.0 | 2 R 4.5/12.0 | 3 R 4.5/11.0 | 4 R 4.5/14.0 | 5 R 4.5/16.0 |
| 7 | N 9.2/ 0.0 | 5 R 8.3/ 1.0 | 5 R 8.2/ 2.0 | 4 R 8.1/ 3.0 | 5 R 8.0/ 3.5 | 4 R 7.4/ 4.0 | 4 R 7.2/ 6.0 | 2 R 7.0/ 7.0 | 3 R 6.9/ 8.0 | 2 R 6.1/ 9.0 | 2 R 5.8/10.0 | 4.5 R 5.2/12.0 |
| 8 | 10 R 8.2/ 2.0 | 9 R 8.0/ 3.0 | 9 R 8.0/ 4.0 | 8 R 7.8/ 4.5 | 7 R 7.5/ 5.0 | 5 R 7.0/ 6.0 | 5 R 7.0/ 7.0 | 5 R 7.0/ 8.0 | 5 R 6.5/ 8.0 | 5 R 6.2/ 8.0 | 5 R 5.5/10.0 | 5 R 4.8/14.0 |
| 9 | 3 YR 8.1/ 5.0 | 10 R 7.5/ 5.0 | 10 R 7.5/ 6.0 | 9 R 7.2/ 6.0 | 8 R 7.0/ 6.0 | 6 R 6.5/ 7.0 | 6 R 7.0/ 8.0 | 5 R 6.5/ 8.0 | 5 R 6.2/ 8.0 | 5 R 6.0/10.0 | 5 R 5.5/10.0 | 5 R 5.0/14.0 |
| 10 | 3 YR 7.8/ 7.0 | 10 R 7.0/ 7.0 | 9 R 7.0/ 8.0 | 8 R 6.8/ 8.0 | 8 R 6.8/ 8.0 | 7 R 6.5/ 8.0 | 7 R 6.5/ 9.0 | 6 R 6.5/ 9.0 | 5.5 R 6.2/ 9.0 | 5.5 R 6.0/10.0 | 5 R 5.2/11.0 | 5 R 5.0/14.0 |
| 11 | 2 YR 7.2/10.0 | 10 R 6.5/ 8.0 | 9 R 6.4/ 9.0 | 9 R 6.3/ 9.5 | 8 R 6.2/10.0 | 8 R 6.1/11.0 | 7 R 6.0/11.0 | 7 R 6.0/11.0 | 7 R 5.8/11.0 | 6 R 5.5/12.0 | 6 R 5.0/12.0 | 5.5 R 5.0/14.0 |
| 12 | 2 YR 6.2/12.0 | 2 YR 6.2/11.0 | 1 YR 6.0/12.0 | 1 YR 5.8/12.0 | 10 R 5.7/12.0 | 10 R 5.5/12.0 | 9 R 5.3/12.0 | 8 R 5.2/12.0 | 8 R 5.2/12.0 | 7 R 5.3/12.0 | 6 R 5.5/12.0 | 6 R 5.0/12.0 |
| | | | | | MAERZ AND PAUL—PLATE 2 | | | | | | | |
| 1 | N 9.0/ | 7 R 8.5/ 1.0 | 7 R 8.0/ 2.5 | 5 R 8.0/ 3.0 | 5 R 7.7/ 4.0 | 4 R 7.2/ 4.0 | 4 R 7.0/ 5.0 | 4 R 6.8/ 6.0 | 3 R 6.5/ 8.0 | 2 R 6.0/ 8.0 | 2 R 5.5/10.0 | 3 R 4.5/12.0 |
| 2 | 5 R 8.5/ 1.5 | 5 R 8.0/ 4.0 | 5 R 7.6/ 4.0 | 5 R 7.3/ 4.0 | 4 R 7.0/ 5.0 | 4 R 7.0/ 6.0 | 4 R 7.0/ 7.0 | 4 R 6.7/ 7.0 | 3 R 6.3/ 8.0 | 3 R 6.0/ 9.0 | 2 R 5.2/10.0 | 2 R 4.6/12.5 |
| 3 | 3 R 8.0/ 4.0 | 2 R 7.5/ 5.0 | 2 R 7.2/ 7.0 | 2 R 7.0/ 7.0 | 2 R 7.0/ 7.5 | 2 R 7.0/ 8.0 | 2 R 7.0/ 8.0 | 2 R 6.7/ 8.0 | 2 R 6.5/ 9.0 | 2 R 6.0/10.0 | 2 R 5.0/10.0 | 3 R 4.4/13.0 |
| 4 | 7 RP 6.5/ 7.0 | 9 RP 6.3/ 9.0 | 9 RP 6.3/ 9.0 | 9 RP 6.2/ 9.0 | 9 RP 6.2/ 9.0 | 9 RP 6.2/ 9.0 | 10 RP 6.2/10.0 | 1 R 6.0/10.0 | 2 R 5.6/10.0 | 2 R 5.3/11.0 | 3 R 5.0/12.0 | 4 R 4.2/14.0 |
| 5 | 8 RP 6.0/11.0 | 8 RP 5.8/11.0 | 8 RP 5.6/11.0 | 9 RP 5.4/11.0 | 9 RP 5.4/11.0 | 9 RP 5.2/11.0 | 10 RP 5.2/11.0 | 10 RP 5.0/12.0 | 1 R 5.0/12.0 | 2 R 5.0/12.0 | 3 R 4.5/12.0 | 4 R 4.0/14.0 |
| 6 | 8 RP 5.2/15.0 | 8 RP 5.2/13.0 | 8 RP 5.0/13.0 | 9 RP 5.0/13.0 | 9 RP 5.0/13.0 | 9 RP 5.0/13.0 | 10 RP 4.8/13.0 | 10 RP 4.8/13.0 | 1 R 4.6/13.0 | 2 R 4.4/13.0 | 3 R 4.2/13.0 | 4 R 4.0/15.0 |
| 7 | N 9.1/ | 5 R 8.5/ 2.0 | 5 R 8.0/ 3.0 | 5 R 8.0/ 3.0 | 5 R 7.8/ 4.0 | 5 R 7.5/ 5.0 | 4 R 7.0/ 5.0 | 3 R 7.0/ 6.0 | 3 R 7.0/ 7.0 | 3 R 6.5/ 8.0 | 2.5 R 5.8/10.0 | 3 R 4.8/12.0 |
| 8 | 5 YR 8.5/ 1.5 | 10 R 8.0/ 2.0 | 9 R 8.0/ 3.0 | 8 R 8.0/ 4.0 | 7 R 8.0/ 4.0 | 6 R 7.7/ 5.0 | 5 R 7.5/ 6.0 | 5 R 7.3/ 6.0 | 5 R 6.8/ 8.0 | 5 R 6.4/ 8.0 | 4 R 6.2/ 9.0 | 4 R 5.0/13.0 |
| 9 | 5 YR 8.0/ 3.0 | 10 R 7.6/ 4.0 | 10 R 7.2/ 4.6 | 10 R 7.2/ 4.6 | 10 R 7.0/ 5.0 | 8 R 6.8/ 6.0 | 6 R 7.0/ 7.0 | 5.5 R 7.0/ 8.0 | 5 R 6.5/ 9.0 | 5 R 6.0/10.0 | 4 R 5.2/10.0 | 4 R 5.0/13.0 |
| 10 | 2 YR 7.5/ 6.0 | 10 R 7.5/ 7.0 | 9 R 7.4/ 7.0 | 8 R 7.3/ 7.5 | 7 R 7.2/ 7.5 | 7 R 7.0/ 8.0 | 6 R 6.8/ 8.0 | 6 R 6.5/ 8.0 | 5.5 R 6.0/ 9.0 | 5.5 R 5.5/10.0 | 5 R 5.2/12.0 | 5 R 5.0/14.0 |
| 11 | 1 YR 7.0/10.0 | 1 YR 6.8/10.0 | 10 R 6.6/10.0 | 10 R 6.4/10.0 | 10 R 6.2/10.0 | 9 R 6.0/10.0 | 9 R 6.0/10.0 | 8 R 5.8/10.0 | 8 R 5.6/10.0 | 7 R 5.4/11.0 | 7 R 5.2/12.0 | 6 R 5.0/14.0 |
| 12 | 2 YR 6.0/12.0 | 2 YR 5.9/11.0 | 2 YR 5.8/11.0 | 10 R 5.7/11.0 | 10 R 5.6/11.0 | 10 R 5.5/12.0 | 9 R 5.4/12.0 | 9 R 5.3/12.0 | 9 R 5.2/12.0 | 8 R 5.1/13.0 | 8 R 5.0/14.0 | 8 R 5.0/12.0 |
| | | | | | MAERZ AND PAUL—PLATE 3 | | | | | | | |
| 1 | 10 Y 8.0/ 0.5 | 5 YR 8.0/ 2.0 | 2 YR 7.8/ 2.0 | 10 R 7.5/ 2.0 | 8 R 7.0/ 3.0 | 5 R 6.7/ 3.0 | 5 R 6.5/ 4.0 | 5 R 6.2/ 5.0 | 4 R 5.8/ 6.0 | 4 R 5.0/ 8.0 | 4 R 5.0/ 7.0 | 4.5 R 4.0/12.0 |
| 2 | 5 R 7.8/ 2.0 | 5 R 7.5/ 3.0 | 5 R 7.2/ 3.5 | 5 R 6.8/ 4.0 | 5 R 6.5/ 4.5 | 4 R 6.3/ 5.0 | 4 R 6.1/ 5.5 | 4 R 5.8/ 6.0 | 4 R 5.5/ 6.5 | 4 R 5.2/ 7.0 | 4 R 5.0/ 9.0 | 4.5 R 3.9/12.0 |
| 3 | 5 R 7.5/ 3.0 | 4.5 R 6.5/ 4.0 | 4.5 R 6.4/ 5.0 | 4.5 R 6.2/ 6.0 | 4 R 6.0/ 6.0 | 4 R 5.8/ 6.5 | 4 R 5.6/ 7.0 | 4.5 R 5.4/ 7.5 | 4.5 R 5.2/ 7.5 | 4 R 5.0/ 8.0 | 4.5 R 4.0/10.0 | 4.5 R 3.9/13.0 |
| 4 | 8 RP 6.0/ 7.0 | 10 RP 5.7/ 8.0 | 10 RP 5.6/ 8.0 | 10 RP 5.5/ 8.0 | 10 RP 5.4/ 8.0 | 10 RP 5.3/ 8.0 | 10 RP 5.2/ 8.0 | 10 RP 5.0/ 8.0 | 10 RP 4.8/ 8.0 | 2 R 4.6/10.0 | 3 R 4.2/10.0 | 4.5 R 3.8/13.0 |
| 5 | 5 RP 5.5/ 8.0 | 6 RP 5.3/ 8.5 | 7 RP 5.2/ 9.0 | 7 RP 5.1/ 9.5 | 8 RP 5.0/10.0 | 9 RP 4.8/10.5 | 10 RP 4.6/11.0 | 1 R 4.4/11.5 | 2 R 4.2/12.0 | 3 R 4.0/12.5 | 4 R 4.0/13.0 | 4.5 R 3.8/14.0 |
| 6 | 5 RP 4.5/14.0 | 6 RP 4.3/14.0 | 7 RP 4.3/14.0 | 8 RP 4.2/14.0 | 9 RP 4.2/14.0 | 9 RP 4.2/14.0 | 10 RP 4.0/14.0 | 1 R 4.0/14.0 | 2 R 4.0/14.0 | 3 R 4.0/14.0 | 4 R 4.0/14.0 | 4.5 R 3.8/15.0 |
| 7 | 5 Y 8.0/ 0.4 | 5 YR 8.0/ 2.0 | 2 YR 7.8/ 2.0 | 10 R 7.5/ 2.0 | 8 R 7.2/ 5.0 | 5 R 6.7/ 3.0 | 5 R 6.5/ 4.0 | 5 R 6.2/ 5.0 | 4 R 5.8/ 6.0 | 4 R 5.5/ 8.0 | 4 R 5.0/ 8.0 | 4.5 R 4.0/12.0 |
| 8 | 10 YR 7.5/ 2.0 | 2 YR 7.0/ 3.0 | 10 R 7.0/ 3.0 | 9 R 6.6/ 3.0 | 8 R 6.3/ 3.0 | 7 R 6.0/ 4.0 | 6 R 5.8/ 4.0 | 6 R 5.8/ 5.0 | 6 R 5.5/ 6.0 | 5 R 5.2/ 6.0 | 4.5 R 4.5/ 8.0 | 4.5 R 4.0/12.0 |
| 9 | 5 YR 7.5/ 4.0 | 2 YR 6.5/ 4.0 | 1 YR 6.4/ 4.0 | 10 R 6.2/ 4.5 | 8 R 6.0/ 5.0 | 7 R 6.3/ 5.0 | 6 R 6.0/ 6.0 | 6 R 5.7/ 6.0 | 5 R 5.7/ 7.0 | 5 R 5.3/ 7.0 | 5 R 4.5/10.0 | 4.5 R 4.0/12.0 |
| 10 | 5 YR 6.7/ 6.0 | 9 R 6.2/ 6.0 | 9 R 6.0/ 6.5 | 9 R 5.9/ 7.5 | 9 R 5.8/ 8.0 | 8 R 5.6/ 8.0 | 7 R 5.5/ 8.0 | 7 R 5.4/ 8.0 | 6 R 5.1/ 8.5 | 6 R 4.8/ 9.0 | 5 R 4.5/10.0 | 5 R 4.0/12.0 |
| 11 | 4 YR 6.0/ 8.0 | 10 R 5.7/ 9.0 | 10 R 5.6/ 9.0 | 10 R 5.5/ 9.0 | 10 R 5.4/ 9.0 | 9 R 5.3/ 9.0 | 9 R 5.2/ 9.0 | 9 R 4.8/ 9.5 | 8 R 4.6/10.0 | 7 R 4.4/10.5 | 7 R 4.2/11.0 | 6.5 R 4.0/11.0 |
| 12 | 3 YR 5.7/11.0 | 2.5YR 5.3/10.5 | 2 YR 5.2/10.0 | 1 YR 5.1/10.0 | 1 YR 5.1/10.0 | 10 R 4.9/10.5 | 10 R 4.9/10.0 | 10 R 4.8/10.0 | 10 R 4.4/10.5 | 9 R 4.3/11.0 | 9 R 4.0/11.0 | 8 R 3.9/11.0 |
| | | | | | MAERZ AND PAUL—PLATE 4 | | | | | | | |
| 1 | 10 Y 7.0/ 0.5 | 10 YR 7.0/ 0.5 | 5 YR 6.8/ 1.0 | 10 R 6.5/ 1.5 | 10 R 6.5/ 2.0 | 8 R 6.2/ 2.3 | 7 R 6.0/ 2.5 | 5 R 5.8/ 2.7 | 3 R 5.5/ 3.0 | 2 R 5.5/ 6.0 | 2 R 4.5/ 6.0 | 4.5 R 3.8/10.0 |
| 2 | 10 R 7.0/ 1.5 | 5 R 6.8/ 1.8 | 5 R 6.5/ 2.0 | 5 R 6.2/ 2.5 | 5 R 6.2/ 2.6 | 5 R 6.0/ 2.8 | 5 R 6.0/ 3.0 | 5 R 5.7/ 3.5 | 4 R 5.3/ 4.0 | 3 R 5.0/ 5.0 | 3 R 4.5/ 8.0 | 4.5 R 3.7/10.0 |
| 3 | 2 R 6.0/ 3.0 | 2 R 5.8/ 3.5 | 2 R 5.8/ 3.5 | 3 R 5.7/ 4.0 | 3 R 5.5/ 4.0 | 3 R 5.3/ 4.2 | 3 R 5.2/ 4.5 | 3 R 5.0/ 5.0 | 3 R 4.8/ 5.5 | 3 R 4.7/ 6.0 | 4 R 4.5/ 8.0 | 5 R 3.6/10.0 |
| 4 | 10 RP 5.3/ 6.0 | 10 RP 5.0/ 5.0 | 10 RP 5.0/ 5.5 | 10 RP 5.0/ 6.0 | 10 RP 5.0/ 6.0 | 1 R 5.0/ 7.0 | 1 R 5.0/ 7.0 | 1 R 4.8/ 7.0 | 2 R 4.8/ 7.5 | 2 R 4.5/ 8.0 | 3 R 4.0/ 9.0 | 5 R 3.5/11.0 |
| 5 | 8 RP 4.8/ 7.0 | 9 RP 4.5/ 8.0 | 9 RP 4.5/ 8.0 | 10 RP 4.5/ 9.0 | 10 RP 4.5/ 9.0 | 10 RP 4.3/10.0 | 10 RP 4.3/10.0 | 1 R 4.2/10.0 | 1 R 4.1/10.0 | 2 R 4.0/10.0 | 4 R 4.0/ 9.0 | 5 R 3.5/11.0 |
| 6 | 9 RP 4.0/12.0 | 9 RP 4.0/10.0 | 9 RP 4.0/10.0 | 9 RP 4.0/10.0 | 9 RP 4.0/10.0 | 10 RP 4.0/10.0 | 1 R 4.0/10.0 | 1 R 4.0/10.0 | 1 R 4.0/10.0 | 3 R 4.0/10.0 | 4 R 4.0/10.0 | 5 R 3.5/11.0 |
| 7 | 10 Y 7.0/ 0.5 | 10 YR 7.0/ 0.5 | 5 YR 6.8/ 1.0 | 10 R 6.5/ 1.5 | 10 R 6.5/ 2.0 | 8 R 6.2/ 2.3 | 7 R 6.0/ 2.5 | 5 R 5.8/ 2.7 | 3 R 5.5/ 3.0 | 2 R 5.5/ 6.0 | 2 R 4.5/ 6.0 | 4.5 R 4.0/10.0 |
| 8 | 10 YR 7.0/ 2.0 | 9 R 6.8/ 2.2 | 9 R 6.6/ 2.4 | 8 R 6.4/ 2.6 | 8 R 6.2/ 2.8 | 7 R 6.0/ 3.0 | 6 R 6.0/ 3.0 | 6 R 5.8/ 3.5 | 5 R 5.5/ 4.0 | 5 R 5.0/ 5.0 | 4.5 R 4.5/ 7.0 | 4.5 R 3.9/10.0 |
| 9 | 5 YR 6.7/ 3.0 | 2 YR 6.5/ 3.0 | 1 YR 6.3/ 3.0 | 10 R 6.2/ 3.0 | 10 R 6.2/ 3.0 | 9 R 6.0/ 3.0 | 8 R 5.8/ 4.0 | 7 R 5.6/ 4.0 | 7 R 5.3/ 4.0 | 6 R 5.0/ 5.0 | 5 R 4.3/ 8.0 | 4.5 R 3.9/10.0 |
| 10 | 5 YR 6.0/ 5.0 | 5 YR 5.8/ 5.0 | 4 YR 5.8/ 5.0 | 3 YR 5.8/ 5.0 | 2 YR 5.8/ 5.0 | 1 YR 5.8/ 5.0 | 10 R 5.6/ 5.0 | 9 R 5.4/ 5.0 | 9 R 5.2/ 5.0 | 8 R 5.0/ 5.0 | 6 R 4.2/ 8.0 | 5 R 3.8/11.0 |
| 11 | 5 YR 6.5/ 7.0 | 4 YR 6.2/ 6.0 | 3 YR 6.0/ 6.0 | 3 YR 5.7/ 6.0 | 2 YR 5.5/ 6.0 | 1 YR 5.3/ 6.0 | 1 YR 5.2/ 6.0 | 10 R 5.0/ 6.0 | 10 R 4.8/ 6.0 | 9 R 4.5/ 7.0 | 8 R 4.2/ 9.0 | 6 R 3.8/11.0 |
| 12 | 4 YR 5.0/10.0 | 4 YR 4.9/10.0 | 3 YR 4.8/10.0 | 3 YR 4.6/10.0 | 3 YR 4.5/10.0 | 3 YR 4.4/10.0 | 2 YR 4.3/10.0 | 2 YR 4.2/10.0 | 1 YR 4.1/10.0 | 10 R 4.0/10.0 | 9 R 3.9/10.0 | 7 R 3.7/11.0 |
| | | | | | MAERZ AND PAUL—PLATE 5 | | | | | | | |
| 1 | 10 Y 6.0/ 0.7 | 10 YR 5.8/ 2.0 | 5 YR 5.8/ 2.0 | 3 YR 5.8/ 2.0 | 7 R 5.5/ 2.5 | 7 R 4.8/ 3.0 | 7 R 5.0/ 3.0 | 7 R 5.0/ 3.0 | 5 R 4.8/ 3.0 | 5 R 4.5/ 4.0 | 5 R 4.1/ 6.0 | 4.5 R 3.5/10.0 |
| 2 | 5 YR 6.0/ 1.0 | 8 R 5.5/ 2.0 | 7 R 5.5/ 2.0 | 6 R 5.5/ 2.5 | 6 R 5.2/ 3.0 | 5 R 5.0/ 3.0 | 5 R 4.5/ 4.0 | 5 R 4.5/ 4.0 | 5 R 4.3/ 4.5 | 5 R 4.0/ 5.0 | 5 R 3.8/ 6.0 | 5 R 3.2/10.0 |
| 3 | 5 R 5.8/ 2.5 | 5 R 5.5/ 2.7 | 5 R 5.4/ 2.7 | 5 R 5.2/ 2.7 | 5 R 5.0/ 3.0 | 5 R 4.8/ 4.0 | 5 R 4.6/ 4.0 | 5 R 4.4/ 4.0 | 5 R 4.2/ 4.0 | 5 R 4.0/ 5.0 | 5 R 3.7/ 7.0 | 5 R 3.3/11.0 |
| 4 | 1 R 4.8/ 4.0 | 1 R 4.7/ 5.0 | 2 R 4.6/ 5.0 | 2 R 4.5/ 5.0 | 3 R 4.4/ 5.0 | 3 R 4.2/ 5.0 | 4 R 4.1/ 5.0 | 4 R 4.0/ 5.0 | 4 R 4.0/ 6.0 | 4 R 4.0/ 6.0 | 5 R 3.5/ 8.0 | 5 R 3.3/12.0 |
| 5 | 10 RP 4.8/ 7.0 | 1 R 4.2/ 6.0 | 1 R 4.2/ 6.0 | 2 R 4.2/ 6.0 | 2 R 4.2/ 6.0 | 2 R 4.2/ 6.0 | 2 R 4.2/ 6.0 | 2.5 R 4.2/ 6.0 | 3 R 4.0/ 7.0 | 4 R 3.8/ 8.0 | 4.5 R 3.5/10.0 | 5 R 3.2/12.0 |
| 6 | 9 RP 3.8/10.0 | 10 RP 3.8/ 9.0 | 10 RP 3.8/ 9.0 | 10 RP 3.8/10.0 | 1 R 3.8/10.0 | 1 R 3.8/10.0 | 1 R 3.8/10.0 | 2 R 3.8/10.0 | 2 R 3.8/10.0 | 3 R 3.8/10.0 | 5 R 3.5/10.0 | 6 R 3.0/13.0 |
| 7 | 10 Y 6.0/ 0.7 | 10 YR 5.8/ 2.0 | 5 YR 5.8/ 2.0 | 3 YR 5.8/ 2.0 | 7 R 5.5/ 2.5 | 7 R 4.8/ 3.0 | 7 R 5.0/ 3.0 | 7 R 5.0/ 3.0 | 5 R 4.8/ 3.0 | 5 R 4.5/ 4.0 | 5 R 4.1/ 6.0 | 4.5 R 3.5/10.0 |
| 8 | 10 YR 6.0/ 2.0 | 5 YR 5.6/ 2.0 | 3 YR 5.5/ 2.0 | 1 YR 5.4/ 2.0 | 8 R 5.3/ 2.0 | 6 R 5.3/ 2.5 | 6 R 5.0/ 3.0 | 6 R 5.0/ 3.5 | 6 R 4.8/ 3.5 | 6 R 4.4/ 4.0 | 5 R 4.0/ 6.0 | 5 R 3.5/10.0 |
| 9 | 7 YR 5.7/ 3.0 | 1 YR 5.5/ 4.0 | 1 YR 5.4/ 4.0 | 10 R 5.2/ 4.0 | 10 R 5.0/ 4.0 | 9 R 4.8/ 4.0 | 8 R 4.5/ 4.0 | 7 R 4.4/ 4.0 | 6 R 4.3/ 5.0 | 6 R 4.3/ 6.0 | 5 R 4.0/ 7.0 | 4.5 R 3.5/10.0 |
| 10 | 5 YR 5.5/ 5.0 | 2 YR 5.0/ 4.0 | 2 YR 4.8/ 4.0 | 1 YR 4.8/ 4.0 | 1 YR 4.6/ 4.0 | 10 R 4.5/ 4.0 | 9 R 4.4/ 4.5 | 9 R 4.2/ 5.0 | 8 R 4.0/ 5.5 | 8 R 3.8/ 6.0 | 6.5 R 3.8/ 8.0 | 6 R 3.5/10.0 |
| 11 | 4.5YR 5.0/ 6.0 | 4 YR 4.4/ 6.0 | 3 YR 4.3/ 6.0 | 2 YR 4.2/ 6.0 | 1 YR 4.1/ 6.0 | 10 R 4.0/ 6.0 | 10 R 3.8/ 6.0 | 10 R 3.8/ 6.0 | 9 R 3.7/ 7.0 | 9 R 3.6/ 7.0 | 8 R 3.5/ 8.0 | 7 R 3.2/10.0 |
| 12 | 5 YR 4.5/10.0 | 4 YR 4.4/ 8.0 | 3 YR 4.3/ 8.0 | 2 YR 4.2/ 8.0 | 1 YR 4.1/ 8.0 | 1 YR 4.0/ 8.0 | 10 R 3.9/ 8.0 | 10 R 3.8/ 8.0 | 9 R 3.7/ 8.0 | 9 R 3.6/ 8.0 | 8 R 3.5/ 8.0 | 8 R 3.3/ 9.0 |

TABLE II.—*Continued*

MAERZ AND PAUL—PLATE 6

| No. | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 Y 5.2/ 0.6 | 8 YR 5.0/ 1.0 | 6 YR 5.0/ 1.5 | 4 YR 5.0/ 2.0 | 2 YR 5.0/ 2.0 | 9 R 4.9/ 2.0 | 7 R 4.8/ 2.2 | 7 R 4.6/ 2.4 | 6 R 4.4/ 2.8 | 5 R 4.1/ 3.5 | 5 R 4.0/ 4.5 | 4.5 R 3.0/ 8.0 |
| 2 | 5 YR 5.5/ 1.5 | 10 R 4.5/ 2.0 | 8 R 4.7/ 2.0 | 6 R 4.8/ 2.0 | 5 R 4.7/ 2.3 | 5 R 4.6/ 2.6 | 5 R 4.5/ 3.0 | 5 R 4.5/ 3.3 | 5 R 4.4/ 3.6 | 5 R 4.0/ 4.0 | 5 R 4.0/ 4.5 | 5 R 3.0/ 8.0 |
| 4 | 10 RP 4.2/ 4.0 | 1 R 4.4/ 4.2 | 2 R 4.0/ 4.4 | 5 R 4.8/ 2.0 | 5 R 4.4/ 2.8 | 5 R 4.3/ 3.0 | 5 R 4.2/ 3.3 | 5 R 4.1/ 3.6 | 5 R 4.0/ 4.0 | 5 R 4.0/ 4.5 | 5 R 4.0/ 4.5 | 5 R 3.0/ 8.5 |
| 5 | 9 RP 3.8/ 6.0 | 10 RP 3.6/ 6.0 | 10 RP 3.5/ 6.0 | 2 R 4.0/ 4.6 | 2 R 3.9/ 4.8 | 3 R 3.8/ 5.0 | 3 R 3.8/ 5.2 | 4 R 3.7/ 5.5 | 4 R 3.7/ 5.8 | 4.5 R 3.7/ 6.0 | 5 R 3.4/ 5.0 | 5 R 3.0/ 9.0 |
| 5 | 9 RP 3.8/ 6.0 | 10 RP 3.6/ 4.2 | 10 RP 3.5/ 6.0 | 2 R 4.0/ 4.6 | 2 R 3.9/ 4.8 | 3 R 3.8/ 5.0 | 3 R 3.8/ 5.2 | 4 R 3.7/ 5.5 | 4 R 3.7/ 5.8 | 4.5 R 3.7/ 6.0 | 5 R 3.4/ 5.0 | 5 R 3.0/ 8.5 |
| 6 | 10 RP 3.2/ 8.0 | 1 R 3.3/ 8.0 | 1 R 3.2/ 8.0 | 1 R 3.2/ 8.0 | 1 R 3.5/ 6.0 | 1 R 3.4/ 6.0 | 2 R 3.4/ 6.0 | 2 R 3.4/ 6.0 | 2 R 3.3/ 6.0 | 3 R 3.3/ 7.0 | 4 R 3.6/ 6.0 | 5 R 3.0/ 9.0 |
| 7 | 5 Y 5.3/ 0.5 | 4 YR 5.0/ 1.2 | 2 YR 5.0/ 1.8 | 1 YR 5.2/ 2.0 | 1 R 3.1/ 8.0 | 2 R 3.1/ 8.0 | 3 R 3.1/ 8.0 | 3 R 3.1/ 9.0 | 4 R 3.1/ 9.0 | 4 R 3.1/ 9.0 | 4 R 3.0/ 8.0 | 5 R 3.0/ 9.5 |
| 8 | 10 YR 5.2/ 1.0 | 10 R 5.1/ 1.6 | 10 R 5.1/ 1.7 | 10 R 4.9/ 1.8 | 9 R 5.2/ 2.0 | 7 R 5.2/ 2.2 | 6 R 5.0/ 2.5 | 6 R 4.7/ 2.7 | 5 R 4.5/ 3.0 | 5 R 4.2/ 4.0 | 5 R 4.0/ 4.5 | 5 R 3.0/10.0 |
| 9 | 7 YR 5.0/ 2.0 | 5 YR 4.8/ 2.5 | 3 YR 4.7/ 2.6 | 2 YR 4.6/ 2.7 | 10 R 4.8/ 1.9 | 8 R 4.7/ 2.0 | 7 R 4.6/ 2.5 | 6 R 4.5/ 3.0 | 5 R 4.4/ 3.5 | 5 R 4.2/ 4.0 | 5 R 4.0/ 4.5 | 4 R 3.0/ 8.0 |
| 10 | 5 YR 4.7/ 4.0 | 4 YR 4.6/ 4.0 | 3 YR 4.5/ 4.0 | 2 YR 4.4/ 4.0 | 1 YR 4.5/ 2.1 | 10 R 4.5/ 3.0 | 9 R 4.4/ 3.2 | 8 R 4.4/ 3.5 | 7 R 4.3/ 3.7 | 6 R 4.2/ 4.0 | 6 R 4.0/ 5.0 | 6 R 3.0/ 8.0 |
| 11 | 5 YR 4.2/ 5.0 | 4 YR 4.0/ 5.0 | 3 YR 4.0/ 4.0 | 2 YR 4.0/ 4.5 | 1 YR 4.2/ 4.0 | 10 R 4.4/ 4.0 | 9 R 4.0/ 4.2 | 8 R 4.0/ 4.4 | 8 R 4.0/ 4.6 | 8 R 4.0/ 4.8 | 7 R 4.0/ 5.0 | 6 R 3.0/ 7.0 |
| 12 | 5 YR 3.8/ 9.0 | 4 YR 3.7/ 9.0 | 4 YR 3.7/ 9.0 | 4 YR 3.6/ 9.0 | 3 YR 3.5/ 9.0 | 3 YR 3.4/ 9.0 | 2 YR 3.3/ 9.0 | 2 YR 3.3/ 9.0 | 1 YR 3.2/ 9.0 | 1 YR 3.1/ 9.0 | 10 R 3.0/ 9.0 | 10 R 3.0/ 9.0 |

MAERZ AND PAUL—PLATE 7

| No. | A | C | E | H | J | L | A | C | E | H | J | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 Y 4.2/ 0.5 | 10 YR 3.8/ 0.5 | 10 R 3.6/ 1.5 | 10 R 3.4/ 2.0 | 6 R 3.0/ 3.5 | 6 R 2.2/ 6.0 | N 2.5/ | 5 Y 2.5/ 0.3 | 5 YR 2.0/ 0.5 | 5 YR 2.0/ 1.0 | 5 YR 2.0/ 1.5 | 10 R 2.0/ 3.0 |
| 2 | 5 YR 4.0/ 0.6 | 10 YR 4.0/ 0.8 | 5 R 3.8/ 1.5 | 5 R 3.5/ 2.5 | 6 R 3.2/ 4.0 | 6.5 R 2.5/ 6.0 | 5 Y 2.3/ 0.2 | 10 YR 2.2/ 0.2 | 5 YR 2.2/ 0.3 | 5 YR 2.0/ 1.0 | 5 YR 2.0/ 2.0 | 10 R 2.0/ 3.0 |
| 3 | 5 R 4.0/ 1.0 | 5 R 3.9/ 1.5 | 5 R 3.8/ 2.0 | 5 R 3.5/ 3.0 | 5 R 3.1/ 4.0 | 6.5 R 2.3/ 6.0 | 5 Y 2.0/ 0.2 | 5 Y 2.0/ 0.3 | 10 YR 2.0/ 0.7 | 5 YR 2.0/ 1.0 | 5 YR 2.0/ 1.5 | 10 R 2.0/ 3.0 |
| 4 | 10 RP 3.5/ 2.0 | 1 R 3.5/ 2.0 | 3 R 3.5/ 3.5 | 4 R 3.2/ 4.0 | 5 R 3.0/ 4.0 | 6.5 R 2.5/ 6.0 | 5 YR 2.0/ 0.7 | 5 YR 2.0/ 0.5 | 5 YR 1.8/ 0.8 | 5 YR 1.8/ 1.5 | 5 YR 2.0/ 2.0 | 2 YR 2.0/ 3.0 |
| 5 | 10 RP 3.3/ 4.0 | 1 R 3.1/ 3.5 | 2 R 3.1/ 3.5 | 3 R 3.0/ 4.0 | 5 R 3.0/ 4.5 | 7 R 2.3/ 6.0 | 5 YR 1.8/ 1.0 | 5 YR 1.8/ 1.3 | 5 YR 1.8/ 1.5 | 5 YR 1.8/ 1.8 | 5 YR 1.8/ 2.0 | 2 YR 2.0/ 2.5 |
| 6 | 10 RP 3.0/ 5.5 | 1 R 3.0/ 5.0 | 1 R 3.0/ 5.5 | 3 R 3.0/ 6.0 | 5 R 2.8/ 6.0 | 8 R 2.4/ 6.0 | 10 R 2.0/ 2.0 | 1 YR 2.0/ 2.0 | 2 YR 2.0/ 2.0 | 3 YR 2.0/ 2.0 | 4 YR 2.0/ 2.0 | 5 YR 2.0/ 3.0 |
| 7 | 5 Y 4.0/ 0.7 | 5 YR 4.0/ 1.0 | 10 R 3.8/ 1.0 | 9 R 3.4/ 2.0 | 7 R 3.0/ 4.0 | 6 R 2.3/ 5.0 | 5 Y 2.6/ 0.1 | 5 Y 2.5/ 0.2 | 10 YR 2.3/ 0.3 | 5 YR 2.0/ 0.5 | 5 YR 2.0/ 1.0 | 10 R 2.0/ 2.0 |
| 8 | 2 Y 4.0/ 1.0 | 10 R 3.9/ 1.0 | 10 R 3.8/ 2.0 | 7 R 3.5/ 2.0 | 7 R 3.0/ 4.0 | 8 R 2.7/ 6.0 | 5 Y 2.5/ 0.2 | 5 Y 2.2/ 0.3 | 10 YR 2.0/ 0.4 | 10 YR 2.0/ 0.5 | 5 YR 2.0/ 1.0 | 2 YR 2.0/ 2.5 |
| 9 | 10 YR 3.8/ 1.5 | 5 YR 3.6/ 1.5 | 10 R 3.4/ 2.0 | 9 R 3.0/ 2.0 | 8 R 3.0/ 4.0 | 9 R 2.9/ 5.0 | 5 Y 2.5/ 0.3 | 5 Y 2.3/ 0.4 | 10 YR 2.0/ 0.5 | 5 YR 2.0/ 1.0 | 5 YR 2.0/ 1.5 | 5 YR 2.0/ 3.0 |
| 10 | 7 YR 3.8/ 2.0 | 6 YR 3.7/ 2.0 | 5 YR 3.7/ 2.0 | 2 YR 3.5/ 3.0 | 1 YR 3.0/ 4.0 | 10 R 2.8/ 4.5 | 5 Y 2.5/ 0.5 | 5 Y 2.3/ 0.6 | 10 YR 2.3/ 0.7 | 5 YR 2.2/ 1.0 | 5 YR 2.2/ 1.7 | 5 YR 2.3/ 3.0 |
| 11 | 6 YR 3.5/ 3.0 | 5 YR 3.5/ 3.0 | 4 YR 3.2/ 3.5 | 1 YR 3.0/ 3.5 | 1 YR 3.0/ 4.0 | 10 R 2.7/ 4.5 | 5 Y 2.5/ 1.0 | 2 Y 2.2/ 1.2 | 10 YR 2.2/ 1.5 | 10 YR 2.2/ 2.0 | 8 YR 2.2/ 1.5 | 5 YR 2.4/ 3.0 |
| 12 | 6 YR 3.0/ 4.5 | 6 YR 3.0/ 4.0 | 5 YR 3.0/ 4.0 | 3 YR 3.0/ 4.0 | 2 YR 2.8/ 4.0 | 1 YR 2.6/ 4.5 | 5 Y 2.5/ 2.0 | 3 Y 2.5/ 2.0 | 1 Y 2.5/ 2.0 | 10 YR 2.5/ 2.0 | 8 YR 2.5/ 2.0 | 5 YR 2.5/ 2.0 |

MAERZ AND PAUL—PLATE 8

| No. | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | N 9.1/ | 5 Y 9.0/ 1.0 | 6 Y 9.0/ 1.5 | 8 Y 9.0/ 2.5 | 8 Y 9.0/ 3.0 | 9 Y 9.0/ 4.0 | 9 Y 9.0/ 4.5 | 9 Y 9.0/ 5.0 | 9 Y 9.0/ 5.5 | 9 Y 9.0/ 6.0 | 9 Y 9.0/ 8.0 | 9 Y 8.7/11.0 |
| 2 | 5 YR 9.0/ 2.0 | 10 YR 8.7/ 2.0 | 2 Y 8.8/ 3.0 | 3 Y 8.8/ 3.3 | 3 Y 8.8/ 3.6 | 3 Y 8.8/ 4.0 | 3 Y 8.8/ 4.5 | 3 Y 8.8/ 5.0 | 3 Y 8.7/ 5.5 | 4 Y 8.6/ 6.0 | 4 Y 8.5/ 7.5 | 4 Y 8.2/10.0 |
| 3 | 5 YR 8.5/ 3.0 | 8 YR 8.4/ 3.0 | 10 YR 8.4/ 4.0 | 1 Y 8.4/ 4.0 | 1 Y 8.4/ 4.0 | 2 Y 8.4/ 4.5 | 3 Y 8.4/ 5.0 | 5 Y 8.4/ 5.5 | 5 Y 8.4/ 6.0 | 5 Y 8.4/ 7.0 | 5 Y 8.4/ 8.0 | 4 Y 8.3/10.0 |
| 4 | 5 YR 8.2/ 4.0 | 8 YR 8.2/ 4.0 | 9 YR 8.2/ 4.5 | 10 YR 8.2/ 5.0 | 10 YR 8.2/ 5.0 | 10 YR 8.2/ 5.5 | 1 Y 8.2/ 5.5 | 1 Y 8.2/ 6.0 | 2 Y 8.2/ 6.5 | 2 Y 8.2/ 7.0 | 3 Y 8.2/ 8.0 | 3 Y 8.2/ 9.0 |
| 5 | 4 YR 8.0/ 4.5 | 7 YR 8.0/ 4.0 | 8 YR 8.0/ 4.5 | 9 YR 8.0/ 5.0 | 9 YR 8.0/ 5.0 | 10 YR 8.0/ 5.0 | 1 Y 8.0/ 5.0 | 1 Y 8.0/ 5.5 | 1 Y 8.0/ 5.5 | 1 Y 8.0/ 6.0 | 2 Y 8.0/ 7.0 | 2 Y 8.0/ 9.0 |
| 6 | 2 YR 7.8/ 5.0 | 5 YR 8.0/ 6.0 | 8 YR 8.0/ 6.0 | 8 YR 7.8/ 6.0 | 8 YR 7.8/ 6.0 | 10 YR 7.8/ 6.0 | 10 YR 7.6/ 6.0 | 10 YR 7.6/ 6.5 | 10 YR 7.6/ 7.0 | 10 YR 7.6/ 7.5 | 10 YR 7.6/ 7.5 | 1 Y 7.5/ 9.0 |
| 7 | 1 YR 7.3/ 7.0 | 3 YR 7.3/ 6.0 | 4 YR 7.4/ 6.2 | 5 YR 7.4/ 6.5 | 6 YR 7.4/ 7.0 | 6 YR 7.4/ 7.2 | 7 YR 7.4/ 7.7 | 7 YR 7.1/ 7.7 | 7 YR 7.4/ 8.2 | 8 YR 7.4/ 8.2 | 8 YR 7.4/ 8.5 | 9 YR 7.3/ 9.0 |
| 8 | 1 YR 7.1/ 8.0 | 2 YR 7.1/ 8.0 | 3 YR 7.2/ 8.0 | 3 YR 7.3/ 8.0 | 4 YR 7.3/ 8.0 | 5 YR 7.3/ 8.5 | 5 YR 7.2/ 8.5 | 5 YR 7.2/ 8.5 | 5 YR 7.2/ 8.5 | 6 YR 7.2/ 9.0 | 7 YR 7.1/10.0 | |
| 9 | 10 R 7.0/10.0 | 1 YR 7.0/ 9.5 | 2 YR 7.0/ 9.5 | 3 YR 7.0/ 9.5 | 4 YR 7.0/ 9.5 | 5 YR 7.0/ 9.5 | 5 YR 7.0/ 9.5 | 5 YR 7.0/ 9.5 | 5 YR 7.0/ 9.5 | 5 YR 7.0/ 9.5 | 5 YR 7.0/ 9.5 | 5 YR 7.0/10.0 |
| 10 | 10 R 7.0/10.0 | 2 YR 7.0/10.0 | 2 YR 7.0/10.0 | 3 YR 7.0/10.0 | 3 YR 7.0/10.0 | 3 YR 7.0/10.0 | 4 YR 7.0/10.0 | 4 YR 7.0/10.0 | 4 YR 7.0/10.0 | 4 YR 7.0/11.0 | 4 YR 7.0/11.0 | 4.5YR 7.0/12.0 |
| 11 | 1 YR 6.8/11.0 | 2 YR 6.8/11.0 | 2 YR 6.9/11.0 | 3 YR 7.0/11.0 | 3 YR 7.0/11.0 | 3 YR 7.0/11.0 | 3 YR 7.0/11.0 | 3 YR 7.0/11.0 | 3 YR 7.0/11.0 | 3 YR 7.0/11.0 | 3 YR 7.0/11.0 | 3 YR 7.0/12.0 |
| 12 | 1 YR 6.5/12.0 | 1 YR 6.5/12.0 | 1 YR 6.5/12.0 | 1 YR 6.5/12.0 | 1 YR 6.5/12.0 | 1.5YR 6.5/12.0 | 1.5YR 6.5/12.0 | 2 YR 6.5/12.0 | 2 YR 6.5/12.0 | 2 YR 6.5/12.0 | 2 YR 6.5/12.0 | 2 YR 6.5/12.0 |

MAERZ AND PAUL—PLATE 9

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 Y 8.5/ 0.7 | 10 Y 8.5/ 1.5 | 10 Y 8.4/ 2.2 | 10 Y 8.4/ 2.8 | 10 Y 8.3/ 3.5 | 10 Y 8.2/ 4.4 | 10 Y 8.2/ 4.6 | 10 Y 8.2/ 4.8 | 9.5 Y 8.1/ 5.0 | 9.5 Y 8.1/ 6.0 | 9.5 Y 8.1/ 7.0 | 9.5 Y 8.1/10.0 |
| 2 | 8 YR 8.3/ 1.5 | 4 Y 8.2/ 2.5 | 4 Y 8.1/ 3.0 | 4 Y 8.2/ 3.5 | 4.5 Y 8.2/ 4.0 | 5 Y 8.1/ 4.5 | 5 Y 8.2/ 5.0 | 4.5 Y 8.2/ 5.5 | 4.5 Y 8.2/ 6.0 | 5 Y 8.1/ 7.0 | 5 Y 8.0/ 8.0 | 5 Y 8.0/ 9.0 |
| 3 | 8 YR 8.0/ 2.0 | 10 YR 8.0/ 3.0 | 2 Y 8.0/ 4.0 | 3 Y 8.0/ 4.3 | 4 Y 8.0/ 4.7 | 4 Y 8.0/ 5.0 | 4.5 Y 8.1/ 5.3 | 4.5 Y 8.0/ 5.5 | 4.5 Y 8.0/ 6.0 | 4.5 Y 8.0/ 7.0 | 5 Y 8.0/ 8.0 | 5 Y 8.0/ 9.0 |
| 4 | 6 YR 8.0/ 3.5 | 9.5YR 7.9/ 4.2 | 9.5YR 7.8/ 5.0 | 10 YR 7.7/ 5.0 | 10 YR 7.8/ 5.2 | 1 Y 7.9/ 5.1 | 1 Y 7.9/ 5.6 | 2 Y 7.9/ 5.8 | 3 Y 8.0/ 6.0 | 3 Y 8.0/ 7.0 | 4 Y 7.8/ 8.0 | 4.5 Y 7.7/ 9.0 |
| 5 | 5 YR 7.8/ 4.0 | 8 YR 8.0/ 5.0 | 9 YR 8.0/ 5.3 | 9 YR 8.0/ 5.5 | 9 YR 8.0/ 5.7 | 1 Y 7.9/ 6.0 | 1 Y 7.9/ 6.0 | 1 Y 7.8/ 6.5 | 2 Y 7.8/ 7.0 | 3 Y 7.8/ 7.5 | 4 Y 7.7/ 8.5 | 4.5 Y 7.7/ 9.2 |
| 6 | 4 YR 7.6/ 4.5 | 8 YR 7.5/ 5.5 | 8 YR 7.5/ 5.6 | 8 YR 7.5/ 5.7 | 8 YR 7.5/ 5.8 | 9 YR 7.5/ 6.0 | 10 YR 7.5/ 6.2 | 10 YR 7.4/ 6.7 | 10 YR 7.4/ 7.4 | 10 YR 7.4/ 8.0 | 10 YR 7.3/ 9.0 | 10 YR 7.3/10.0 |
| 7 | 1 YR 7.2/ 5.0 | 5 YR 7.3/ 6.0 | 6 YR 7.3/ 6.0 | 6 YR 7.3/ 6.0 | 6 YR 7.3/ 6.0 | 6 YR 7.3/ 7.0 | 7 YR 7.3/ 7.0 | 7 YR 7.3/ 8.0 | 7 YR 7.3/ 8.0 | 8 YR 7.3/ 9.0 | 8 YR 7.3/10.0 | |
| 8 | 2 YR 7.0/ 7.0 | 4 YR 7.0/ 7.0 | 5 YR 7.2/ 7.0 | 5 YR 7.2/ 7.0 | 5 YR 7.2/ 7.0 | 5 YR 7.2/ 8.0 | 5 YR 7.2/ 9.0 | 5 YR 7.2/ 9.0 | 6 YR 7.2/ 9.0 | 6 YR 7.2/ 9.0 | 7 YR 7.2/ 9.0 | 8 YR 7.2/10.0 |
| 9 | 3 YR 7.0/ 8.0 | 4 YR 7.0/ 8.0 | 4 YR 7.0/ 8.0 | 4 YR 7.0/ 8.5 | 4 YR 7.0/ 8.5 | 5 YR 7.0/ 9.0 | 5 YR 7.0/ 9.0 | 5 YR 7.0/ 9.0 | 5 YR 7.0/ 9.0 | 5 YR 7.0/10.0 | 5 YR 7.0/11.0 | |
| 10 | 2 YR 6.8/ 8.0 | 4 YR 6.8/ 9.0 | 4 YR 6.8/ 9.0 | 4 YR 6.8/ 9.0 | 4 YR 6.8/ 9.0 | 4 YR 6.8/ 9.0 | 4 YR 6.8/10.0 | 4 YR 6.8/10.0 | 4 YR 6.8/10.0 | 4 YR 6.8/10.0 | 4 YR 6.8/11.0 | 4 YR 6.8/12.0 |
| 11 | 2 YR 6.5/10.0 | 3 YR 6.5/10.0 | 3 YR 6.5/10.0 | 3 YR 6.5/10.0 | 3 YR 6.5/10.0 | 3 YR 6.5/10.0 | 3 YR 6.5/10.0 | 3 YR 6.5/11.0 | 4 YR 6.5/11.0 | 4 YR 6.5/12.0 | 4 YR 6.5/13.0 | |
| 12 | 4 YR 6.2/14.0 | 4 YR 6.2/14.0 | 3 YR 6.2/14.0 | 3 YR 6.2/14.0 | 3 YR 6.2/14.0 | 3 YR 6.2/14.0 | 3 YR 6.2/14.0 | 3 YR 6.2/14.0 | 3 YR 6.2/14.0 | 3 YR 6.2/14.0 | 2 YR 6.2/14.0 | 2 YR 6.2/14.0 |

MAERZ AND PAUL—PLATE 10

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 Y 8.0/ 1.0 | 9 Y 8.0/ 2.0 | 9 Y 8.0/ 3.0 | 10 Y 8.0/ 3.5 | 10 Y 8.0/ 4.0 | 10 Y 8.0/ 4.3 | 10 Y 8.0/ 4.6 | 10 Y 8.0/ 5.0 | 10 Y 8.0/ 5.5 | 10 Y 8.0/ 6.0 | 10 Y 8.0/ 6.5 | 10 Y 8.0/ 8.0 |
| 2 | 10 YR 8.0/ 2.0 | 3 Y 8.0/ 3.0 | 4 Y 8.0/ 3.5 | 5 Y 8.0/ 4.0 | 6 Y 8.0/ 4.0 | 6 Y 8.0/ 4.5 | 6 Y 8.0/ 4.7 | 6 Y 8.0/ 5.0 | 6 Y 8.0/ 5.3 | 6 Y 8.0/ 5.6 | 6 Y 8.0/ 6.0 | 6 Y 8.0/ 8.0 |
| 3 | 10 YR 7.8/ 2.0 | 1 Y 7.5/ 2.0 | 2 Y 7.5/ 3.0 | 2 Y 7.5/ 4.0 | 3 Y 7.5/ 4.2 | 3 Y 7.5/ 4.4 | 4 Y 7.5/ 4.6 | 4 Y 7.5/ 4.8 | 4 Y 7.5/ 5.0 | 4 Y 7.5/ 5.5 | 5 Y 7.5/ 6.0 | 5 Y 7.5/ 7.0 |
| 4 | 8 YR 7.5/ 3.0 | 10 YR 7.4/ 4.0 | 1 Y 7.4/ 4.2 | 2 Y 7.4/ 4.4 | 2 Y 7.4/ 4.6 | 3 Y 7.4/ 4.8 | 3 Y 7.5/ 5.0 | 3 Y 7.5/ 5.2 | 4 Y 7.5/ 5.4 | 4 Y 7.5/ 5.7 | 4 Y 7.5/ 6.0 | 4 Y 7.3/ 7.0 |
| 5 | 5 YR 7.7/ 3.0 | 9 YR 7.5/ 4.0 | 10 YR 7.2/ 4.0 | 1 Y 7.2/ 4.0 | 1 Y 7.2/ 4.0 | 1 Y 7.2/ 4.0 | 1 Y 7.0/ 5.0 | 1 Y 7.0/ 5.0 | 2 Y 7.0/ 5.0 | 2 Y 7.0/ 5.0 | 2 Y 7.0/ 5.5 | 2.5 Y 7.0/ 6.0 |
| 6 | 5 YR 7.2/ 4.0 | 8 YR 7.0/ 5.0 | 9 YR 7.0/ 5.0 | 10 YR 7.0/ 5.0 | 10 YR 7.0/ 5.0 | 10 YR 7.0/ 5.0 | 10 YR 7.0/ 5.0 | 1 Y 7.0/ 5.0 | 2 Y 7.0/ 5.0 | 2 Y 7.0/ 5.0 | 2 Y 7.0/ 5.5 | 2.5 Y 7.0/ 6.0 |
| 7 | 5 YR 6.5/ 6.0 | 8 YR 6.6/ 6.2 | 8 YR 6.6/ 6.4 | 8 YR 6.6/ 6.6 | 8 YR 6.6/ 6.8 | 9 YR 6.6/ 7.0 | 9 YR 6.6/ 7.2 | 9 YR 6.6/ 7.4 | 9 YR 6.6/ 7.6 | 9 YR 6.6/ 7.8 | 10 YR 6.6/ 8.0 | 10 YR 6.6/ 9.0 |
| 8 | 3 YR 6.2/ 7.0 | 4 YR 6.2/ 7.2 | 4 YR 6.3/ 7.4 | 4 YR 6.3/ 7.6 | 5 YR 6.4/ 7.8 | 5 YR 6.4/ 8.0 | 5 YR 6.4/ 8.0 | 5 YR 6.4/ 8.0 | 6 YR 6.4/ 8.0 | 6 YR 6.4/ 8.0 | 7 YR 6.4/ 8.0 | 7 YR 6.4/ 9.0 |
| 9 | 3 YR 6.0/ 8.0 | 3 YR 6.0/ 8.0 | 3 YR 6.0/ 8.0 | 4 YR 6.0/ 8.0 | 4 YR 6.0/ 9.0 | 4 YR 6.0/ 9.0 | 4 YR 6.0/ 9.0 | 4 YR 6.0/ 9.0 | 4 YR 6.0/ 9.0 | 5 YR 6.0/ 9.0 | 5 YR 6.0/ 9.0 | 5 YR 6.0/10.0 |
| 10 | 3 YR 6.0/ 8.0 | 2 YR 6.0/ 8.0 | 2 YR 6.0/ 8.0 | 2 YR 6.0/ 8.0 | 3 YR 6.0/ 8.5 | 3 YR 6.0/ 8.5 | 4 YR 6.0/ 9.0 | 4 YR 6.0/ 9.0 | 4 YR 6.0/ 9.0 | 4 YR 6.0/10.0 | 4 YR 6.0/10.0 | 4.5YR 6.0/11.0 |
| 11 | 3 YR 6.0/10.0 | 3 YR 6.0/11.0 | 3 YR 6.0/11.0 | 3 YR 6.0/11.0 | 3 YR 6.0/11.0 | 3 YR 6.0/11.0 | 4 YR 6.0/11.0 | 4 YR 6.0/11.0 | 4 YR 6.0/11.0 | 4 YR 6.0/11.0 | 4 YR 6.0/11.0 | 4 YR 6.0/11.0 |
| 12 | 3 YR 5.8/12.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.8/11.0 | 3 YR 5.7/12.0 |

MAERZ AND PAUL—PLATE 11

TABLE II.—*Continued*

MAERZ AND PAUL—PLATE 12

| No. | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 Y 7.0/ 1.0 | 10 Y 7.0/ 2.0 | 10 Y 7.0/ 2.5 | 10 Y 7.0/ 3.0 | 10 Y 6.9/ 3.5 | 10 Y 6.8/ 4.0 | 10 Y 6.8/ 4.3 | 10 Y 6.8/ 4.6 | 10 Y 6.8/ 5.0 | 10 Y 6.8/ 5.5 | 10 Y 6.8/ 6.0 | 10 Y 6.8/ 7.0 |
| 2 | 10 YR 7.0/ 1.5 | 5 Y 7.0/ 3.0 | 6 Y 6.9/ 3.3 | 7 Y 6.9/ 3.5 | 8 Y 6.9/ 3.8 | 8 Y 6.8/ 4.0 | 8 Y 6.8/ 4.0 | 8 Y 6.7/ 4.0 | 8 Y 6.7/ 4.3 | 8 Y 6.6/ 4.5 | 8 Y 6.5/ 4.5 | 8 Y 6.0/ 5.5 |
| 3 | 8 YR 6.8/ 2.0 | 2 Y 6.5/ 3.0 | 3 Y 6.5/ 3.0 | 4 Y 6.5/ 3.0 | 4 Y 6.5/ 3.5 | 4 Y 6.5/ 3.5 | 4 Y 6.5/ 3.5 | 4 Y 6.5/ 3.5 | 4 Y 6.5/ 3.5 | 4 Y 6.5/ 4.0 | 4 Y 6.5/ 4.0 | 5 Y 6.2/ 5.0 |
| 4 | 7 YR 6.8/ 2.0 | 10 YR 7.0/ 3.5 | 1 Y 6.9/ 3.5 | 2 Y 6.8/ 3.5 | 3 Y 6.7/ 4.0 | 4 Y 6.6/ 4.0 | 4 Y 6.5/ 4.0 | 4 Y 6.4/ 4.0 | 5 Y 6.3/ 4.0 | 5 Y 6.3/ 4.0 | 5 Y 6.2/ 4.0 | 5 Y 6.0/ 5.0 |
| 5 | 7 YR 6.5/ 2.5 | 10 YR 6.0/ 3.5 | 10 YR 6.0/ 4.0 | 10 YR 6.0/ 4.0 | 10 YR 6.2/ 4.0 | 1 Y 6.3/ 4.0 | 1 Y 6.3/ 4.0 | 2 Y 6.4/ 4.0 | 3 Y 6.4/ 4.0 | 4 Y 6.5/ 4.0 | 5 Y 6.2/ 4.8 | 5 Y 6.0/ 5.0 |
| 6 | 5 YR 6.0/ 3.0 | 8 YR 6.2/ 4.0 | 8 YR 6.2/ 4.0 | 9 YR 6.2/ 4.0 | 9 YR 6.2/ 4.0 | 10 YR 6.2/ 4.5 | 10 YR 6.2/ 4.5 | 1 Y 6.2/ 4.5 | 2 Y 6.2/ 4.5 | 3 Y 6.2/ 4.5 | 4 Y 6.2/ 4.5 | 4 Y 6.0/ 5.0 |
| 7 | 4 YR 6.0/ 4.0 | 7 YR 6.0/ 4.0 | 7 YR 6.0/ 4.0 | 8 YR 6.0/ 4.0 | 8 YR 6.0/ 4.5 | 8 YR 6.0/ 4.5 | 8 YR 6.0/ 5.0 | 9 YR 6.0/ 5.0 | 9 YR 6.0/ 5.0 | 10 YR 6.0/ 5.0 | 10 YR 5.7/ 5.5 | 1 Y 5.5/ 6.0 |
| 8 | 4 YR 5.7/ 6.0 | 5 YR 5.8/ 6.0 | 5 YR 5.7/ 6.0 | 5 YR 5.7/ 3.6 | 5 YR 5.7/ 6.0 | 6 YR 5.6/ 6.0 | 7 YR 5.6/ 6.0 | 7 YR 5.6/ 6.0 | 8 YR 5.6/ 6.0 | 9 YR 5.6/ 6.0 | 9 YR 5.6/ 6.0 | 9 YR 5.5/ 7.0 |
| 9 | 4 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 6 YR 5.3/ 6.0 | 6 YR 5.3/ 6.5 | 6 YR 5.3/ 7.0 | 7 YR 5.2/ 7.5 |
| 10 | 4 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.0 | 5 YR 5.3/ 6.5 | 5 YR 5.3/ 7.0 | 5 YR 5.2/ 8.0 |
| 11 | 4 YR 5.1/ 8.0 | 4 YR 5.1/ 8.0 | 4 YR 5.1/ 8.0 | 4 YR 5.1/ 8.5 | 4 YR 5.1/ 8.5 | 4 YR 5.1/ 8.5 | 5 YR 5.1/ 8.5 | 5 YR 5.1/ 8.5 | 5 YR 5.1/ 8.5 | 5 YR 5.0/ 9.0 | 5 YR 5.0/ 9.0 | 5 YR 5.0/ 9.0 |
| 12 | 4 YR 5.0/ 9.0 | 4 YR 5.0/ 9.0 | 4 YR 5.0/ 9.0 | 4 YR 5.0/ 9.5 | 4 YR 5.0/ 9.5 | 4 YR 5.0/ 9.5 | 4 YR 5.0/ 9.5 | 4 YR 5.0/ 9.5 | 4 YR 5.0/ 9.5 | 4 YR 5.0/10.0 | 4 YR 5.0/10.0 | 5 YR 5.0/10.0 |

MAERZ AND PAUL—PLATE 13

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 GY 6.0/ 0.2 | 10 Y 6.0/ 1.0 | 10 Y 6.0/ 2.0 | 10 Y 6.0/ 2.3 | 10 Y 6.0/ 2.5 | 10 Y 6.0/ 2.7 | 10 Y 6.0/ 3.0 | 10 Y 6.0/ 3.3 | 10 Y 6.0/ 3.6 | 10 Y 6.0/ 4.0 | 10 Y 6.0/ 4.5 | 10 Y 6.0/ 5.5 |
| 2 | 5 Y 6.0/ 1.0 | 8 Y 6.0/ 2.0 | 9 Y 6.0/ 2.2 | 9 Y 6.0/ 2.4 | 9 Y 6.0/ 2.6 | 9 Y 6.0/ 2.8 | 9 Y 6.0/ 3.0 | 9 Y 6.0/ 3.3 | 9 Y 6.0/ 3.5 | 9 Y 6.0/ 3.8 | 9 Y 6.0/ 4.0 | 9 Y 6.0/ 5.5 |
| 3 | 10 YR 6.0/ 1.5 | 1 Y 6.0/ 2.0 | 2 Y 6.0/ 2.0 | 3 Y 6.0/ 2.2 | 4 Y 6.0/ 2.4 | 5 Y 6.0/ 2.6 | 5 Y 6.0/ 2.8 | 5 Y 6.0/ 3.0 | 6 Y 6.0/ 3.4 | 6 Y 6.0/ 3.7 | 6 Y 6.0/ 4.0 | 7 Y 6.0/ 5.0 |
| 4 | 10 YR 6.0/ 2.0 | 2 Y 6.0/ 2.0 | 3 Y 6.0/ 2.5 | 3 Y 6.0/ 2.8 | 4 Y 6.0/ 3.0 | 4 Y 6.0/ 3.3 | 5 Y 6.0/ 3.4 | 5 Y 6.0/ 3.6 | 5 Y 6.0/ 3.8 | 5 Y 6.0/ 4.0 | 5 Y 6.0/ 4.2 | 5 Y 6.0/ 5.0 |
| 5 | 8 YR 6.0/ 2.0 | 10 YR 6.0/ 2.3 | 1 Y 6.0/ 2.3 | 2 Y 6.0/ 2.5 | 2 Y 6.0/ 2.7 | 3 Y 6.0/ 3.0 | 4 Y 6.0/ 3.2 | 5 Y 6.0/ 3.5 | 5 Y 6.0/ 3.8 | 5 Y 6.0/ 4.0 | 5 Y 6.0/ 4.3 | 5 Y 6.0/ 5.0 |
| 6 | 5 YR 5.7/ 3.0 | 8 YR 5.8/ 3.0 | 9 YR 5.8/ 3.3 | 9 YR 5.8/ 3.6 | 10 YR 5.8/ 4.0 | 10 YR 5.8/ 4.0 | 1 Y 5.8/ 4.0 | 1 Y 5.8/ 4.0 | 2 Y 5.8/ 4.0 | 2 Y 5.8/ 4.0 | 3 Y 5.8/ 4.0 | 4 Y 5.8/ 5.0 |
| 7 | 5 YR 5.5/ 4.0 | 8 YR 5.5/ 4.0 | 8 YR 5.5/ 4.0 | 8 YR 5.5/ 4.0 | 9 YR 5.5/ 4.0 | 9 YR 5.5/ 4.0 | 9 YR 5.5/ 4.0 | 9 YR 5.5/ 4.0 | 10 YR 5.5/ 4.0 | 10 YR 5.5/ 4.0 | 1 Y 5.5/ 4.0 | 2 Y 5.5/ 5.0 |
| 8 | 4 YR 5.5/ 5.0 | 5 YR 5.5/ 5.0 | 6 YR 5.5/ 5.0 | 6 YR 5.5/ 5.0 | 7 YR 5.5/ 5.0 | 7 YR 5.5/ 5.0 | 8 YR 5.5/ 5.0 | 9 YR 5.5/ 5.0 | 10 YR 5.5/ 5.0 | 10 YR 5.5/ 5.0 | 1 Y 5.5/ 5.0 | 1 Y 5.5/ 5.0 |
| 9 | 4 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 6 YR 5.0/ 6.0 | 6 YR 5.0/ 6.0 | 7 YR 5.0/ 6.0 | 7 YR 5.0/ 6.0 | 7 YR 5.0/ 6.0 | 8 YR 5.0/ 6.0 | 8 YR 5.0/ 6.0 | 9 YR 5.0/ 6.0 | 9 YR 5.0/ 6.0 | 9 YR 5.0/ 6.0 |
| 10 | 4 YR 5.0/ 6.0 | 4 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 6 YR 5.0/ 6.0 | 6 YR 5.0/ 6.0 |
| 11 | 4 YR 5.0/ 7.0 | 4 YR 5.0/ 6.5 | 4 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 | 5 YR 5.0/ 6.0 |
| 12 | 4 YR 4.8/ 8.0 | 4 YR 4.8/ 7.5 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 | 4 YR 4.8/ 7.0 |

MAERZ AND PAUL—PLATE 14

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 GY 5.0/ 0.3 | 10 Y 5.1/ 1.0 | 10 Y 5.0/ 1.2 | 10 Y 5.0/ 1.4 | 10 Y 5.0/ 1.6 | 10 Y 5.0/ 1.8 | 10 Y 5.0/ 2.0 | 10 Y 5.0/ 2.2 | 10 Y 5.0/ 2.5 | 10 Y 5.0/ 3.0 | 10 Y 5.0/ 3.5 | 1 GY 5.0/ 5.5 |
| 2 | 10 Y 5.0/ 0.5 | 10 Y 5.0/ 1.4 | 10 Y 5.0/ 1.6 | 10 Y 5.0/ 1.8 | 10 Y 5.0/ 2.0 | 10 Y 5.0/ 2.2 | 10 Y 5.0/ 2.4 | 10 Y 5.0/ 2.6 | 10 Y 5.0/ 2.8 | 10 Y 5.0/ 3.0 | 9 Y 5.0/ 3.5 | 10 Y 4.8/ 5.0 |
| 3 | 5 YR 5.3/ 1.0 | 10 Y 5.2/ 2.0 | 5 Y 5.2/ 1.5 | 5 Y 5.2/ 2.0 | 5 Y 5.2/ 2.4 | 5 Y 5.2/ 2.7 | 5 Y 5.2/ 3.0 | 5 Y 5.2/ 3.3 | 5 Y 5.2/ 3.5 | 5 Y 5.2/ 3.7 | 7.5 Y 5.2/ 4.0 | 8 Y 4.8/ 5.0 |
| 4 | 5 YR 5.5/ 1.5 | 3 Y 5.5/ 2.0 | 3 Y 5.5/ 2.1 | 4 Y 5.5/ 2.2 | 4 Y 5.5/ 2.3 | 5 Y 5.0/ 2.4 | 5 Y 5.0/ 2.5 | 5 Y 5.0/ 2.8 | 5 Y 5.0/ 2.7 | 5 Y 5.0/ 3.0 | 6 Y 5.2/ 3.5 | 7 Y 5.0/ 4.0 |
| 5 | 5 YR 5.5/ 2.0 | 3 Y 5.2/ 2.0 | 3 Y 5.2/ 2.2 | 3 Y 5.2/ 2.4 | 3 Y 5.2/ 2.6 | 3 Y 5.2/ 2.8 | 3 Y 5.1/ 3.0 | 3 Y 5.1/ 3.2 | 3 Y 5.1/ 3.5 | 4 Y 5.1/ 3.7 | 5 Y 5.1/ 4.0 | 6 Y 5.0/ 5.0 |
| 6 | 5 YR 5.0/ 2.0 | 10 YR 5.0/ 2.0 | 10 YR 5.0/ 2.0 | 10 YR 5.0/ 2.0 | 10 YR 5.0/ 2.5 | 10 YR 5.0/ 3.0 | 10 YR 5.0/ 3.5 | 10 YR 5.0/ 3.6 | 1 Y 5.0/ 3.7 | 3 Y 5.0/ 3.8 | 4 Y 5.0/ 4.0 | 5 Y 5.0/ 4.5 |
| 7 | 5 YR 4.5/ 2.5 | 10 YR 5.0/ 2.5 | 10 YR 5.0/ 3.0 | 10 YR 5.0/ 3.1 | 10 YR 5.0/ 3.2 | 10 YR 5.0/ 3.3 | 10 YR 5.0/ 3.5 | 10 YR 5.0/ 3.6 | 1 Y 5.0/ 3.7 | 1 Y 5.0/ 3.8 | 3 Y 4.8/ 4.0 | 4 Y 4.8/ 5.0 |
| 8 | 5 YR 4.2/ 4.0 | 7 YR 4.5/ 4.0 | 7 YR 4.5/ 4.0 | 8 YR 4.5/ 4.0 | 8 YR 4.5/ 4.0 | 8 YR 4.5/ 4.0 | 9 YR 4.5/ 4.0 | 9 YR 4.5/ 4.0 | 9 YR 4.5/ 4.0 | 10 YR 4.5/ 4.0 | 1 Y 4.5/ 4.5 | 3 Y 4.5/ 5.0 |
| 9 | 5 YR 4.1/ 4.0 | 6 YR 4.2/ 4.0 | 6 YR 4.2/ 4.0 | 7 YR 4.2/ 4.0 | 7 YR 4.2/ 4.0 | 8 YR 4.2/ 4.0 | 8 YR 4.2/ 4.0 | 9 YR 4.2/ 4.0 | 9 YR 4.2/ 4.0 | 9 YR 4.2/ 4.0 | 10 YR 4.3/ 4.0 | 10 YR 4.5/ 4.0 |
| 10 | 5 YR 4.0/ 4.0 | 6 YR 4.1/ 4.0 | 6 YR 4.1/ 4.0 | 6 YR 4.1/ 4.0 | 6 YR 4.1/ 4.0 | 7 YR 4.1/ 4.0 | 7 YR 4.1/ 4.0 | 7 YR 4.1/ 4.0 | 8 YR 4.1/ 4.0 | 8 YR 4.1/ 4.0 | 9 YR 4.2/ 4.0 | 10 YR 4.3/ 4.0 |
| 11 | 5 YR 3.9/ 5.0 | 6 YR 4.0/ 4.5 | 6 YR 4.0/ 4.5 | 6 YR 4.0/ 4.5 | 6 YR 4.0/ 4.5 | 7 YR 4.0/ 4.5 | 7 YR 4.0/ 4.5 | 7 YR 4.0/ 4.5 | 7 YR 4.0/ 4.5 | 7 YR 4.0/ 4.5 | 7 YR 4.0/ 4.5 | 7 YR 4.0/ 5.0 |
| 12 | 4 YR 3.8/ 7.0 | 5 YR 4.0/ 6.0 | 5 YR 4.0/ 6.0 | 5 YR 4.0/ 6.0 | 5 YR 4.0/ 6.0 | 6 YR 4.0/ 5.0 | 6 YR 4.0/ 5.0 | 6 YR 4.0/ 5.0 | 6 YR 4.0/ 5.0 | 6 YR 4.0/ 5.0 | 6 YR 4.0/ 5.0 | 6 YR 4.0/ 5.0 |

MAERZ AND PAUL—PLATE 15

| No. | A | C | E | H | J | L |
|---|---|---|---|---|---|---|
| 1 | 5 Y 4.0/ 0.3 | 10 Y 4.0/ 0.8 | 10 Y 4.0/ 1.5 | 10 Y 4.3/ 2.0 | 10 Y 4.0/ 3.0 | 1 GY 4.0/ 4.0 |
| 2 | 5 Y 4.0/ 0.2 | 7 Y 4.0/ 0.7 | 8 Y 4.0/ 1.0 | 9 Y 4.0/ 1.5 | 1 GY 4.2/ 2.0 | 1 GY 4.0/ 4.0 |
| 3 | 5 Y 4.0/ 0.6 | 5 Y 4.0/ 1.0 | 7 Y 4.0/ 2.0 | 8 Y 4.0/ 2.5 | 10 Y 4.0/ 3.0 | 10 Y 3.9/ 3.8 |
| 4 | 10 YR 4.0/ 0.5 | 10 YR 4.0/ 1.0 | 5 Y 4.0/ 1.5 | 6 Y 4.0/ 2.5 | 10 Y 4.0/ 3.0 | 10 Y 3.9/ 4.0 |
| 5 | 10 YR 4.0/ 0.6 | 10 YR 4.0/ 1.0 | 2 Y 4.0/ 1.0 | 5 Y 4.0/ 2.0 | 8 Y 4.0/ 2.5 | 9 Y 4.0/ 4.0 |
| 6 | 5 YR 4.0/ 1.0 | 8 YR 4.0/ 1.0 | 10 YR 4.0/ 1.5 | 3 Y 4.0/ 2.0 | 2 Y 4.0/ 2.5 | 7 Y 4.0/ 4.0 |
| 7 | 5 YR 4.0/ 1.5 | 8 YR 4.0/ 2.0 | 10 YR 4.0/ 2.0 | 2 Y 4.0/ 2.0 | 4 Y 4.0/ 2.5 | 5 Y 4.0/ 4.0 |
| 8 | 5 YR 4.0/ 2.0 | 8 YR 3.8/ 2.0 | 10 YR 3.8/ 2.0 | 2 Y 3.8/ 2.0 | 3 Y 3.8/ 2.0 | 3 Y 3.8/ 3.0 |
| 9 | 5 YR 3.8/ 2.5 | 8 YR 3.8/ 1.5 | 10 YR 3.8/ 2.0 | 1 Y 3.8/ 2.0 | 2 Y 3.8/ 2.5 | 2 Y 3.9/ 3.0 |
| 10 | 5 YR 3.8/ 3.0 | 8 YR 3.8/ 2.0 | 9 YR 3.8/ 2.0 | 10 YR 3.8/ 2.0 | 1 Y 3.8/ 2.5 | 2 Y 3.8/ 4.0 |
| 11 | 5 YR 3.5/ 3.5 | 7 YR 3.7/ 2.5 | 8 YR 3.8/ 2.5 | 8 YR 4.0/ 2.5 | 9 YR 4.0/ 2.5 | 10 YR 4.0/ 3.0 |
| 12 | 6 YR 3.5/ 4.0 | 7 YR 3.8/ 3.5 | 8 YR 3.8/ 3.0 | 8 YR 3.8/ 2.0 | 9 YR 3.8/ 2.0 | 10 YR 3.5/ 4.0 |

MAERZ AND PAUL—PLATE 16

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 5 GY 3.0/ 0.2 | 5 GY 3.0/ 1.0 | 5 GY 3.0/ 2.0 | 5 GY 3.0/ 3.0 | 5 GY 3.0/ 4.0 | |
| 2 | 5 GY 3.0/ 0.3 | 5 GY 3.0/ 0.8 | 5 GY 3.0/ 2.0 | 5 GY 3.0/ 3.0 | 5 GY 3.0/ 4.0 | |
| 3 | 5 Y 3.0/ 0.3 | 5 GY 3.0/ 0.5 | 5 GY 3.0/ 1.0 | 5 GY 3.0/ 2.0 | 6 GY 3.0/ 3.0 | |
| 4 | 5 Y 3.0/ 0.2 | 10 Y 3.0/ 0.7 | 5 GY 3.0/ 1.3 | 5 GY 3.0/ 2.0 | 6 GY 3.0/ 3.0 | |
| 5 | 5 Y 3.0/ 1.0 | 5 GY 3.0/ 1.0 | 5 GY 3.0/ 1.5 | 5 GY 3.0/ 2.0 | 6 GY 3.0/ 3.0 | |
| 6 | 5 Y 3.0/ 1.0 | 10 Y 3.0/ 1.0 | 10 Y 3.0/ 2.0 | 5 GY 3.0/ 2.0 | 7 GY 3.0/ 2.5 | |
| 7 | 5 Y 3.0/ 1.5 | 7 Y 3.0/ 2.0 | 10 Y 3.0/ 2.0 | 5 GY 3.0/ 2.0 | 7 GY 3.2/ 2.5 | |
| 8 | 5 Y 3.0/ 1.0 | 5 Y 3.0/ 1.5 | 10 Y 3.0/ 1.5 | 10 Y 3.0/ 2.0 | 5 GY 3.0/ 2.0 | |
| 9 | 5 Y 3.0/ 1.0 | 5 Y 3.0/ 2.0 | 10 Y 3.0/ 2.0 | 10 Y 3.0/ 2.0 | 10 Y 3.0/ 3.0 | |
| 10 | 5 Y 2.5/ 2.0 | 5 Y 2.5/ 2.0 | 8 Y 3.0/ 2.0 | 10 Y 3.0/ 2.0 | 2 GY 3.0/ 2.0 | |
| 11 | 4 Y 3.0/ 2.0 | 5 Y 3.0/ 2.0 | 8 Y 3.0/ 2.0 | 10 Y 3.0/ 2.0 | 2 GY 3.0/ 2.0 | |
| 12 | 5 Y 3.0/ 2.0 | 5 Y 3.0/ 2.0 | 10 Y 3.0/ 2.0 | 10 Y 3.0/ 3.0 | 10 Y 3.0/ 3.0 | |

TABLE II—*Continued*

MAERZ AND PAUL—PLATE 17

| No. | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 Y 9.3/ 0.2 | 5 Y 9.1/ 0.8 | 10 Y 9.0/ 2.0 | 10 Y 8.8/ 3.0 | 10 Y 8.8/ 4.0 | 10 Y 8.8/ 4.5 | 10 Y 8.8/ 5.0 | 10 Y 8.8/ 5.5 | 10 Y 8.8/ 6.0 | 10 Y 8.8/ 6.5 | 10 Y 8.8/ 7.0 | 10 Y 8.8/10.0 |
| 2 | 5 GY 8.8/ 0.5 | 10 Y 8.7/ 1.0 | 10 Y 8.6/ 2.0 | 10 Y 8.5/ 2.5 | 10 Y 8.5/ 3.0 | 10 Y 8.5/ 3.5 | 10 Y 8.5/ 4.0 | 10 Y 8.5/ 4.3 | 10 Y 8.5/ 5.0 | 10 Y 8.5/ 5.5 | 0.5GY 8.5/ 6.0 | 0.5GY 8.5/ 9.0 |
| 3 | 5 G 8.5/ 1.0 | 5 GY 8.5/ 2.0 | 5 GY 8.3/ 2.5 | 5 GY 8.3/ 3.0 | 5 GY 8.3/ 3.5 | 5 GY 8.2/ 4.0 | 5 GY 8.2/ 4.5 | 5 GY 8.2/ 5.0 | 5 GY 8.2/ 5.5 | 5 GY 8.2/ 6.0 | 1 GY 8.2/ 6.5 | 1 GY 8.2/ 8.0 |
| 4 | 5 G 8.3/ 1.5 | 10 GY 8.0/ 2.0 | 7 GY 8.1/ 2.5 | 5 GY 8.1/ 3.0 | 5 GY 8.1/ 3.5 | 5 GY 8.1/ 4.0 | 5 GY 8.0/ 4.5 | 5 GY 8.0/ 5.0 | 5 GY 8.0/ 5.5 | 5 GY 8.0/ 6.0 | 4 GY 8.0/ 6.5 | 2.5GY 8.0/ 8.0 |
| 5 | 4 G 8.2/ 1.5 | 10 GY 8.2/ 3.0 | 9 GY 8.1/ 3.3 | 8 GY 8.1/ 3.6 | 8 GY 8.0/ 4.0 | 7 GY 8.0/ 4.3 | 7 GY 8.0/ 4.6 | 7 GY 8.0/ 5.0 | 6 GY 8.0/ 5.5 | 6 GY 8.0/ 6.0 | 6 GY 7.9/ 7.0 | 5 GY 7.8/10.0 |
| 6 | 4 G 8.0/ 3.0 | 10 GY 8.0/ 3.0 | 9 GY 8.0/ 3.3 | 8 GY 8.0/ 3.6 | 8 GY 8.0/ 4.0 | 8 GY 8.0/ 4.5 | 7.5GY 8.0/ 5.0 | 7.5GY 8.0/ 5.5 | 7.5GY 8.0/ 6.0 | 7 GY 8.0/ 6.5 | 6 GY 8.0/ 7.0 | 4.5GY 7.2/ 9.0 |
| 7 | 4 G 7.7/ 4.5 | 10 GY 7.5/ 4.5 | 10 GY 7.4/ 5.0 | 10 GY 7.4/ 5.5 | 10 GY 7.4/ 6.0 | 9 GY 7.3/ 6.0 | 8 GY 7.3/ 6.0 | 8 GY 7.3/ 6.0 | 8 GY 7.3/ 6.5 | 8 GY 7.2/ 6.0 | 7 GY 7.1/ 6.0 | 7 GY 7.1/ 6.5 |
| 8 | 4 G 7.4/ 6.0 | 3 G 7.3/ 6.0 | 2 G 7.3/ 6.0 | 1 G 7.2/ 6.0 | 10 GY 7.1/ 6.0 | 10 GY 7.0/ 6.0 | 10 GY 7.0/ 6.0 | 10 GY 7.0/ 6.2 | 10 GY 7.0/ 6.4 | 9 GY 7.0/ 6.6 | 9 GY 7.0/ 7.0 | 8 GY 6.8/ 8.0 |
| 9 | 4.5 G 7.0/ 7.0 | 2 G 6.8/ 6.0 | 2 G 6.8/ 6.0 | 2 G 6.7/ 6.0 | 2 G 6.6/ 6.0 | 1 G 6.5/ 6.0 | 1 G 6.4/ 6.0 | 1 G 6.4/ 6.0 | 1 G 6.4/ 6.5 | 1 G 6.4/ 6.0 | 1 G 6.4/ 6.5 | 1 G 6.4/ 8.0 |
| 10 | 4.5 G 6.9/ 7.0 | 3 G 6.5/ 6.0 | 2 G 6.4/ 6.0 | 2 G 6.4/ 6.0 | 2 G 6.4/ 6.5 | 2 G 6.3/ 7.0 | 1 G 6.3/ 7.5 | 1 G 6.3/ 8.0 | 1 G 6.3/ 8.5 | 1 G 6.3/ 9.0 | 1 G 6.3/ 9.5 | 10 GY 6.2/11.0 |
| 11 | 4.5 G 6.5/ 7.0 | 4 G 6.4/ 7.0 | 3 G 6.3/ 7.2 | 3 G 6.2/ 7.4 | 3 G 6.1/ 7.6 | 3 G 6.0/ 7.8 | 2 G 6.0/ 8.0 | 2 G 6.0/ 8.3 | 2 G 6.0/ 8.6 | 1 G 6.0/ 8.9 | 1 G 6.0/ 9.2 | 1 G 6.0/11.0 |
| 12 | 4 G 6.0/ 9.0 | 4 G 6.0/ 9.0 | 4 G 6.0/ 9.5 | 4 G 6.0/ 9.5 | 3 G 6.0/ 9.5 | 3 G 6.0/ 9.5 | 3 G 5.9/10.0 | 3 G 5.9/10.0 | 3 G 5.9/10.0 | 2 G 5.9/10.0 | 2 G 5.8/10.0 | 2 G 5.8/11.0 |

MAERZ AND PAUL—PLATE 18

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 Y 9.0/ 1.0 | 10 Y 8.8/ 1.5 | 10 Y 8.6/ 2.0 | 10 Y 8.4/ 3.0 | 10 Y 8.2/ 4.0 | 10 Y 8.2/ 4.5 | 9 Y 8.2/ 5.0 | 9 Y 8.2/ 5.5 | 9 Y 8.2/ 6.0 | 9 Y 8.2/ 6.5 | 9 Y 8.2/ 7.0 | 9.5 Y 8.2/ 9.0 |
| 2 | 5 GY 8.1/ 1.5 | 4 GY 8.0/ 2.0 | 3 GY 8.0/ 2.0 | 2 GY 8.0/ 2.0 | 1 GY 8.0/ 3.0 | 1 GY 8.0/ 4.0 | 1 GY 8.0/ 4.5 | 1 GY 8.0/ 5.0 | 1 GY 8.0/ 5.5 | 1 GY 8.0/ 6.0 | 1 GY 8.0/ 6.8 | 1.5GY 8.0/ 8.0 |
| 3 | 1 G 8.0/ 1.5 | 5 GY 8.0/ 3.0 | 5 GY 8.0/ 3.3 | 4 GY 8.0/ 3.6 | 4 GY 8.1/ 4.0 | 4 GY 8.1/ 4.5 | 3 GY 8.1/ 5.0 | 3 GY 8.1/ 5.5 | 3 GY 8.2/ 6.0 | 3 GY 8.0/ 6.5 | 3 GY 7.9/ 7.0 | 2 GY 7.8/ 8.0 |
| 4 | 1 G 8.0/ 2.0 | 6 GY 8.0/ 3.0 | 5 GY 8.0/ 3.5 | 4.5GY 8.0/ 4.0 | 4.5GY 8.0/ 4.3 | 4 GY 8.0/ 4.6 | 4 GY 8.0/ 5.0 | 4 GY 8.0/ 5.3 | 4 GY 8.0/ 5.6 | 4 GY 7.8/ 6.0 | 4 GY 7.8/ 7.0 | 2.5GY 7.8/ 8.0 |
| 5 | 1 G 8.0/ 2.5 | 9 GY 8.0/ 3.0 | 8 GY 7.9/ 3.5 | 7 GY 7.8/ 4.0 | 7 GY 7.8/ 4.3 | 6 GY 7.8/ 4.6 | 6 GY 7.8/ 5.0 | 6 GY 7.8/ 5.5 | 5.5GY 7.7/ 6.0 | 5 GY 7.6/ 7.0 | 5 GY 7.5/ 8.0 | 4 GY 7.2/ 9.0 |
| 6 | 1 G 7.3/ 3.0 | 10 GY 7.5/ 4.0 | 9 GY 7.5/ 4.0 | 9 GY 7.5/ 4.3 | 9 GY 7.5/ 4.6 | 9 GY 7.5/ 5.0 | 8 GY 7.5/ 5.2 | 8 GY 7.4/ 5.5 | 7 GY 7.3/ 5.7 | 6 GY 7.2/ 6.0 | 5.5GY 7.2/ 6.5 | 5.5GY 7.0/ 8.0 |
| 7 | 2 G 7.0/ 4.0 | 10 GY 7.1/ 5.0 | 10 GY 7.1/ 5.0 | 10 GY 7.3/ 5.0 | 10 GY 7.2/ 5.0 | 9 GY 7.2/ 5.0 | 9 GY 7.1/ 5.5 | 8 GY 7.0/ 5.8 | 8 GY 6.8/ 6.0 | 8 GY 6.8/ 6.5 | 7 GY 6.8/ 7.0 | 6.5GY 6.8/ 8.0 |
| 8 | 3 G 7.0/ 4.5 | 0.5 G 6.8/ 6.0 | 10 GY 7.0/ 6.0 | 10 GY 7.0/ 6.0 | 10 GY 7.0/ 6.6 | 10 GY 7.0/ 7.0 | 10 GY 7.0/ 7.3 | 10 GY 7.0/ 7.6 | 9.5GY 6.9/ 8.0 | 9 GY 6.8/ 8.7 | 9 GY 6.5/10.0 | |
| 9 | 3 G 6.5/ 5.0 | 2 G 6.4/ 5.0 | 2 G 6.4/ 5.5 | 2 G 6.4/ 6.0 | 2 G 6.4/ 6.5 | 1 G 6.4/ 7.0 | 1 G 6.4/ 7.5 | 0.5 G 6.4/ 8.0 | 10 GY 6.4/ 8.5 | 10 GY 6.4/ 9.0 | 10 GY 6.3/10.0 | 9.5GY 6.2/12.0 |
| 10 | 3 G 6.2/ 6.0 | 2 G 6.2/ 6.0 | 2 G 6.2/ 6.3 | 2 G 6.2/ 6.6 | 2 G 6.2/ 7.0 | 2 G 6.2/ 7.3 | 2 G 6.2/ 7.6 | 1 G 6.2/ 8.0 | 1 G 6.1/ 9.0 | 10 GY 6.1/10.0 | 10 GY 6.0/11.0 | 10 GY 5.8/12.0 |
| 11 | 3 G 6.1/ 7.0 | 3 G 6.1/ 7.0 | 3 G 6.1/ 7.5 | 3 G 6.1/ 8.0 | 2.5 G 6.0/ 8.5 | 2.5 G 6.0/ 9.0 | 2 G 6.0/ 9.5 | 2 G 5.9/10.0 | 2 G 5.8/10.5 | 2 G 5.7/11.0 | 1 G 5.6/11.5 | 0.5 G 5.5/12.0 |
| 12 | 4 G 5.5/10.0 | 4 G 5.4/10.0 | 4 G 5.4/10.0 | 4 G 5.4/10.0 | 4 G 5.3/10.0 | 4 G 5.3/10.0 | 3 G 5.3/10.0 | 2.5 G 5.3/10.0 | 2.5 G 5.2/10.0 | 2 G 5.2/10.5 | 2 G 5.2/11.0 | 1 G 5.2/12.0 |

MAERZ AND PAUL—PLATE 19

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5 Y 8.2/ 1.5 | 8 Y 8.0/ 2.0 | 9 Y 8.0/ 2.5 | 9 Y 7.9/ 3.0 | 10 Y 7.9/ 3.5 | 10 Y 7.9/ 4.0 | 10 Y 7.8/ 4.5 | 10 Y 7.8/ 4.8 | 10 Y 7.7/ 5.2 | 10 Y 7.6/ 5.6 | 10 Y 7.5/ 6.0 | 10 Y 6.8/ 7.5 |
| 2 | 3 GY 7.8/ 1.8 | 3 GY 7.8/ 2.5 | 2 GY 7.8/ 3.0 | 3 GY 7.7/ 3.5 | 3 GY 7.7/ 3.7 | 1 GY 7.6/ 4.0 | 1 GY 7.5/ 4.2 | 1 GY 7.5/ 4.4 | 1 GY 7.5/ 4.6 | 1 GY 7.5/ 4.8 | 1 GY 7.4/ 5.0 | 1 GY 7.0/ 6.5 |
| 3 | 5 GY 7.5/ 2.0 | 5 GY 7.6/ 2.5 | 4 GY 7.6/ 2.8 | 4 GY 7.6/ 3.0 | 4 GY 7.5/ 3.2 | 3 GY 7.4/ 3.4 | 3 GY 7.3/ 3.6 | 3 GY 7.2/ 3.8 | 3 GY 7.2/ 4.0 | 3 GY 7.1/ 4.0 | 2 GY 7.0/ 5.0 | 2 GY 6.9/ 6.0 |
| 4 | 8 GY 7.3/ 2.0 | 6 GY 7.2/ 2.5 | 5 GY 7.2/ 3.0 | 5 GY 7.2/ 3.5 | 5 GY 7.2/ 3.8 | 5 GY 7.2/ 4.0 | 5 GY 7.2/ 4.0 | 5 GY 7.1/ 4.0 | 4 GY 7.1/ 4.0 | 4 GY 7.1/ 4.5 | 3 GY 7.0/ 5.0 | 3 GY 6.8/ 6.0 |
| 5 | 9 GY 7.2/ 2.5 | 8 GY 7.1/ 3.0 | 7 GY 7.0/ 3.2 | 7 GY 7.0/ 3.5 | 6 GY 7.0/ 3.7 | 6 GY 6.9/ 4.0 | 5 GY 7.0/ 4.0 | 5 GY 7.0/ 4.0 | 5 GY 7.0/ 4.6 | 5 GY 7.1/ 5.3 | 5 GY 7.0/ 5.6 | 5 GY 6.8/ 6.5 |
| 6 | 10 GY 6.7/ 3.0 | 9 GY 6.7/ 3.0 | 8 GY 6.7/ 3.5 | 8 GY 6.7/ 3.5 | 8 GY 6.7/ 4.2 | 7 GY 6.7/ 4.5 | 7 GY 6.7/ 4.8 | 7 GY 6.7/ 5.0 | 6 GY 6.7/ 5.3 | 6 GY 6.7/ 5.6 | 6 GY 6.7/ 6.0 | 5 GY 6.6/ 7.0 |
| 7 | 0.5 G 6.5/ 4.0 | 10 GY 6.5/ 4.0 | 10 GY 6.5/ 4.2 | 10 GY 6.5/ 4.4 | 10 GY 6.5/ 4.5 | 9 GY 6.5/ 4.6 | 8 GY 6.5/ 4.8 | 8 GY 6.5/ 5.0 | 7 GY 6.5/ 5.2 | 7 GY 6.5/ 5.5 | 7 GY 6.5/ 6.0 | 6 GY 6.3/ 8.0 |
| 8 | 1 G 6.1/ 4.5 | 1 G 6.2/ 5.0 | 10 GY 6.2/ 5.0 | 10 GY 6.2/ 5.0 | 10 GY 6.2/ 5.0 | 10 GY 6.2/ 5.0 | 10 GY 6.3/ 6.0 | 10 GY 6.3/ 6.0 | 10 GY 6.3/ 6.0 | 10 GY 6.3/ 6.0 | 9 GY 6.3/ 7.0 | 8 GY 6.2/ 9.0 |
| 9 | 2 G 6.0/ 5.0 | 1 G 6.0/ 5.0 | 1 G 6.0/ 5.0 | 1 G 6.0/ 5.0 | 10 GY 6.0/ 5.0 | 10 GY 6.0/ 5.0 | 10 GY 6.2/ 5.0 | 10 GY 6.2/ 5.0 | 10 GY 6.2/ 6.0 | 10 GY 6.2/ 6.0 | 10 GY 6.2/ 8.0 | 9.5GY 6.2/10.0 |
| 10 | 2 G 6.0/ 6.0 | 2 G 6.0/ 6.0 | 2 G 6.0/ 6.0 | 1 G 6.0/ 6.0 | 1 G 6.0/ 7.0 | 1 G 6.0/ 7.0 | 1 G 6.0/ 7.0 | 10 GY 6.0/ 8.0 | 10 GY 6.0/ 8.0 | 10 GY 6.0/ 8.0 | 10 GY 6.0/ 8.0 | 10 GY 6.0/10.0 |
| 11 | 3 G 5.8/ 6.0 | 3 G 5.8/ 6.5 | 3 G 5.8/ 7.0 | 2 G 5.8/ 7.5 | 2 G 5.8/ 8.0 | 2 G 5.8/ 8.0 | 2 G 5.8/ 8.0 | 1 G 5.8/ 8.5 | 1 G 5.8/ 9.0 | 1 G 5.8/ 9.5 | 1 G 5.8/10.0 | 0.5 G 5.8/11.0 |
| 12 | 4 G 5.4/ 9.0 | 4 G 5.3/ 9.0 | 4 G 5.3/ 9.0 | 3 G 5.3/ 9.0 | 3 G 5.3/ 9.0 | 3 G 5.2/ 9.0 | 3 G 5.2/ 8.0 | 2 G 5.2/ 8.0 | 2 G 5.2/ 8.0 | 2 G 5.1/ 8.0 | 1 G 5.1/ 9.0 | 1 G 5.3/10.0 |

MAERZ AND PAUL—PLATE 20

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 Y 7.0/ 1.2 | 8 Y 7.0/ 2.0 | 9 Y 6.7/ 2.2 | 10 Y 6.5/ 2.5 | 10 Y 6.5/ 3.0 | 10 Y 6.5/ 3.5 | 10 Y 6.5/ 4.0 | 10 Y 6.5/ 4.2 | 10 Y 6.5/ 4.5 | 10 Y 6.5/ 4.8 | 10 Y 6.5/ 5.0 | 10 Y 6.5/ 6.0 |
| 2 | 5 GY 7.0/ 1.0 | 3 GY 6.8/ 2.0 | 3 GY 6.7/ 2.2 | 2 GY 6.7/ 2.4 | 2 GY 6.6/ 2.7 | 2 GY 6.5/ 3.0 | 2 GY 6.5/ 3.3 | 2 GY 6.4/ 3.5 | 2 GY 6.3/ 3.7 | 2 GY 6.2/ 4.0 | 2 GY 6.1/ 4.2 | 2 GY 5.9/ 4.5 |
| 3 | 6 GY 6.8/ 2.0 | 4 GY 6.7/ 3.0 | 4 GY 6.7/ 3.0 | 4 GY 6.6/ 3.2 | 4 GY 6.6/ 3.4 | 3 GY 6.5/ 3.5 | 3 GY 6.5/ 3.5 | 3 GY 6.4/ 3.5 | 3 GY 6.3/ 3.7 | 3 GY 6.2/ 4.0 | 3 GY 6.1/ 4.2 | 2 GY 6.0/ 5.0 |
| 4 | 8 GY 6.3/ 2.0 | 6 GY 6.2/ 2.8 | 6 GY 6.2/ 3.0 | 5 GY 6.2/ 3.2 | 5 GY 6.2/ 3.3 | 5 GY 6.3/ 3.5 | 5 GY 6.2/ 3.5 | 4 GY 6.2/ 3.8 | 4 GY 6.1/ 4.0 | 4 GY 6.0/ 4.0 | 4 GY 6.0/ 4.5 | 4 GY 6.0/ 5.0 |
| 5 | 9 GY 6.2/ 2.0 | 7 GY 6.2/ 3.0 | 6 GY 6.2/ 3.5 | 6 GY 6.1/ 3.5 | 6 GY 6.1/ 3.5 | 5 GY 6.1/ 3.5 | 5 GY 6.0/ 4.0 | 5 GY 6.0/ 4.0 | 5 GY 6.0/ 4.0 | 5 GY 6.0/ 4.5 | 5 GY 6.0/ 4.5 | 4 GY 5.8/ 5.0 |
| 6 | 10 GY 6.0/ 2.0 | 8 GY 6.0/ 2.5 | 7 GY 6.0/ 3.0 | 7 GY 6.0/ 3.0 | 7 GY 5.9/ 3.5 | 7 GY 5.9/ 3.5 | 7 GY 5.8/ 4.0 | 7 GY 5.8/ 4.0 | 6 GY 5.8/ 4.0 | 5 GY 5.8/ 4.5 | 5 GY 5.7/ 5.4 | 5 GY 5.5/ 6.0 |
| 7 | 2 G 5.8/ 3.0 | 10 GY 5.8/ 4.0 | 9 GY 5.8/ 4.0 | 9 GY 5.8/ 4.0 | 9 GY 5.8/ 4.0 | 8 GY 5.7/ 4.5 | 8 GY 5.7/ 4.5 | 8 GY 5.7/ 4.5 | 8 GY 5.7/ 4.5 | 7 GY 5.6/ 5.0 | 7 GY 5.6/ 5.0 | 7 GY 5.4/ 6.0 |
| 8 | 3 G 5.2/ 4.0 | 1 G 5.1/ 4.0 | 1 G 5.0/ 4.0 | 1 G 5.1/ 4.0 | 1 G 5.1/ 4.0 | 1 G 5.1/ 4.5 | 1 G 5.1/ 4.5 | 1 G 5.1/ 4.5 | 1 G 5.1/ 5.0 | 10 GY 5.1/ 5.0 | 9 GY 5.1/ 5.5 | 9 GY 5.0/ 6.0 |
| 9 | 3 G 5.2/ 5.0 | 2 G 5.1/ 5.0 | 2 G 5.1/ 5.0 | 1 G 5.1/ 5.0 | 1 G 5.1/ 4.5 | 10 GY 5.1/ 5.5 | 10 GY 5.1/ 5.5 | 10 GY 5.1/ 5.5 | 10 GY 5.1/ 5.5 | 10 GY 5.1/ 5.5 | 10 GY 5.1/ 6.0 | 10 GY 5.0/ 7.0 |
| 10 | 3 G 5.0/ 5.5 | 2 G 5.0/ 5.5 | 2 G 5.0/ 5.5 | 2 G 5.0/ 6.0 | 2 G 5.0/ 6.0 | 2 G 5.0/ 6.0 | 2 G 5.0/ 6.0 | 1 G 5.0/ 6.0 | 1 G 5.0/ 6.0 | 1 G 5.0/ 6.0 | 1 G 5.0/ 7.0 | 10 GY 5.0/ 8.0 |
| 11 | 4 G 5.0/ 5.5 | 3 G 4.9/ 5.8 | 3 G 4.9/ 6.0 | 3 G 4.8/ 6.1 | 2 G 4.8/ 6.2 | 2 G 4.8/ 6.4 | 2 G 4.7/ 6.6 | 2 G 4.7/ 6.7 | 2 G 4.7/ 6.8 | 1 G 4.7/ 7.0 | 1 G 4.7/ 7.5 | 10 GY 4.7/ 8.0 |
| 12 | 4 G 5.0/ 8.0 | 4 G 5.0/ 8.0 | 3 G 4.9/ 8.0 | 3 G 4.9/ 8.0 | 3 G 4.8/ 8.0 | 3 G 4.7/ 8.0 | 3 G 4.6/ 8.0 | 2 G 4.5/ 8.0 | 2 G 4.4/ 8.0 | 1 G 4.4/ 8.0 | 1 G 4.3/ 8.0 | 1 G 4.2/ 8.0 |

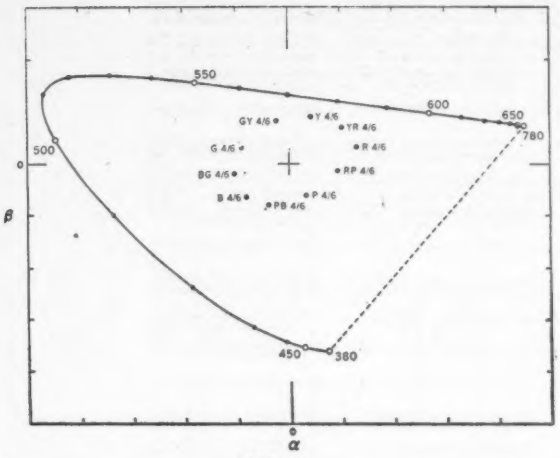


FIG. 8

**Scofield-Judd-Hunter ($\alpha, \beta$)—Diagram Showing Locus of Spectrum Colors, Points Representing 10 Munsell 4/6 Colors, and the Origin or Neutral Point. The Transformation Is According to Equation 6.**

subtractions are of such simple numbers that a calculator is not usually necessary. Note that the scale factor for $V_X - V_Y$ is plotted at 2.5 × that of $V_Z - V_Y$.

Dr. Adams *(3)* is still working to bring theory and practice together to produce a method of plotting I.C.I. data in a uniform color space. To do this successfully it may be necessary some day to correct some of the faults of the I.C.I. system. For various illuminants, for example, it was found desirable to assume separate adaptation of the two "humps" of the $x$ distribution, and for higher chromas to use the function $(V - V_Y)/(10 - V + V_Y)$.

In 1943 Moon and Spencer *(28)* published details of a metric space, using data supplied them by members of the O.S.A. subcommittee on spacing of the Munsell colors *(31)* to develop formulas for a 3-dimensional Euclidean space in which unit distance in any direction was intended to represent equal visual differences. The purpose was fine, but the omega space developed is not nearly so satisfactory as the diagrams in their report might lead one to believe. Figure 14 shows how the Munsell re-notations for value 5/ would be spaced if plotted in Moon and Spencer's metric, $\text{omega}_1$ against $\text{omega}_3$ for a background in which the $X$, $Y$, $Z$ are 0.191, 0.198, 0.220. As may be seen by comparison to other diagrams—Adams' for example—the Moon and Spencer space is not nearly so closely worked out to provide equal spacing as are other methods. For anyone who may wish to experiment, the equations for converting I.C.I. space to the Moon and Spencer metric are as follows:

$$\omega_1 = \frac{2(p_1 - 0.950p_3)}{0.168(1.630 + p_2)^{1/3} - 0.119}$$

$$\omega_3 = \frac{2.270(p_3 - 1.100p_2)^{1.30}}{0.6280(1.800 + p_2)^{1/3} - 0.5210} \qquad (10)$$

When $X$, $Y$, $Z$ *and* $X_0Y_0Z_0$ are the tristimulus values of the color and its background, then

$$p_1 = \frac{X - X_0}{Y_0} = \frac{Y(x/y) - Y_0(x_0/y_0)}{Y_0}$$

$$p_2 = \frac{Y - Y_0}{Y_0} \qquad (10a)$$

$$p_3 = \frac{Z - Z_0}{Z_0} = \frac{Y(z/y) - Y_0(z_0y_0)}{Y_0}$$

Saunderson and Milner *(41)* in 1944, after trying to use the Moon and Spencer space, published a discussion of it, together with a diagram similar to that in Fig. 14.

Later Saunderson and Milner *(42)* studied the Adams' chromatic value diagram, modifying it by the equations:

$$\zeta_1 = (V_X - V_Y)(9.37 + 0.97 \cos \Theta)$$

$$\zeta_3 = (V_Z - V_Y)(3.33 + 0.87 \sin \Theta) \qquad (11)$$

where

$$\tan \Theta = \frac{0.4\ (V_Z - V_Y)}{V_X - V_Y}$$

They found very satisfactory chroma spacing, even for extrapolated chromas, for all values. When used with a third equation, $\zeta_2 = 2V_Y$, a 3-dimensional space model is obtained. The scale for $\zeta_2$ relative to $\zeta_1$ and $\zeta_3$ is, of course, arbitrary. As indicated by Nickerson and Newhall this factor probably can vary from 2½ to 10, depending upon the condition of viewing. Nomographs and a slide rule for easy conversion of I.C.I. data to this modified chromatic value space have been developed by Saunderson and Milner. (They now use $\zeta_2 = 4V_Y$.)

Though other means of graphing or transforming I.C.I. data may have been developed, these seem the chief ones to date.

### 2. Equivalent Data

One of the chief uses of the I.C.I. diagram is that data in I.C.I. terms may be plotted on a diagram and read off in another set of terms that colorimetrically is more descriptive. The shiny red product of our purse manufacturer might have $Y$ and $x$, $y$ equivalents that could be translated to terms of brightness, dominant wave length, and purity, or to terms of Munsell hue, value, and chroma, to the nearest Ostwald chip, or the nearest sample in the Maerz and Paul Color Dictionary, or in Ridgway. Who knows what $Y = 0.074$, $x = 0.506$, $y = 0.312$ means? Yet in daylight it is a dark strong red, no matter what figures may be used in its specification. For transparent standards conversions are also available, as for Lovibond glasses and Wratten filters.

In accord with the four-part provision of ASA Z-44 (1942) war standard for the specification and description of color *(4)* the spectrophotometer is recognized as the basic instrument in color specifications; I.C.I. methods shall be used to reduce these

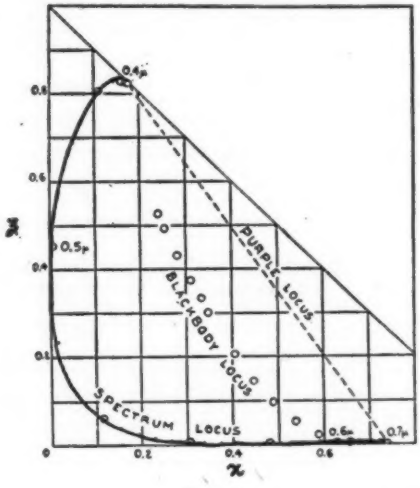


FIG. 9

**Adams' Suggestion for Plotting (x,z) in Place of (x,y) in I.C.I. Diagrams.**

data either to terms of $Y$ and $x$, $y$ or of dominant wave length and purity; the Munsell *Book of Color* is recommended for the popular identification of color and the idealized Munsell system for the precise interpretation of basic (I.C.I.) specifications; and descriptive color names according to the ISCC-NBS system are recommended for use when general comprehensibility is desired and precision is not important. The conversion methods described, or the converted data referred to in this section, follow the provision of this ASA standard either in whole or in part.

### Dominant Wavelength—Purity

Until 1943 when the Munsell re-notations became available in terms of I.C.I., the most widely used system of conversion was from I.C.I. to dominant wave length and purity. It is easy to construct charts for this purpose, but easier still—since 1936—for illuminant *C*, to read it from the large-scale charts of the Hardy *Handbook of Colorimetry (27)*.

The practice of converting to dominant wavelength and purity has little to recommend it except that until 1943 it was about the only thing one could do to get even an approximate color description out of an I.C.I. specification. In daylight a red handbag, for example, has a dominant wave length of 617 mμ, purity 52%. In tungsten light the dominant wave length is about the same, but the purity is nearer to 70%.

To construct a chart for dominant wavelength and purity, plot I.C.I. $(x,y)$-data for the spectrum colors [Table of Resolution V from original I.C.I. report *(6)*, Table XXIV of the Hardy handbook, or Table XXVIII, page 669, November 1944 *Journal of the Optical Society of America*] and for the illuminant that is to be used. Three illuminants are standardized for colorimetry by the I.C.I. and it is usual in this country to use I.C.I. illuminant A for incandescent tungsten, and I.C.I. illuminant C for daylight. In England considerable work is referred to I.C.I. illuminant B:

| | $x$ | $y$ |
|---|---|---|
| Illuminant A—a gas-filled tungsten lamp | 0.4476 | 0.4075 |
| B—lamp and filter to represent noon sunlight | 0.3484 | 0.3518 |
| C—lamp and filter to represent average daylight | 0.3101 | 0.3163 |

By means of straight lines connect each point plotted for a spectrum color to the central illuminant point. Any $(x,y)$-point that lies on a single straight line through the illuminant point has the same dominant wave length as the spectral color on the same side of the illuminant point with which it is connected. The spectral color on the opposite side of the illuminant point is its complementary wave length. Excitation purity is 100% for the spectral colors, and for colors lying on the straight line drawn to connect the ends of the spectrum. Fifty per cent purity is halfway between the spectrum boundary line and the illuminant point, 10% is 10% of the distance, and so forth. These lines may be drawn in and labeled. If this is done accurately on a large scale, one may read just as precisely for dominant wave length and purity as he may wish.

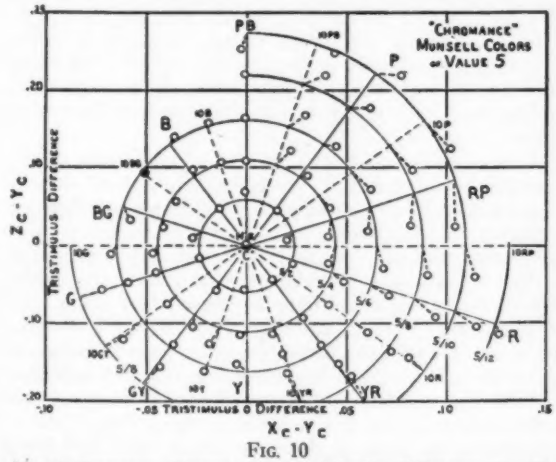


Fig. 10

Adams' Chromance Diagram. I.C.I. Tristimulus Differences $X_c$—$Y_c$ Are Plotted Against $Z_c$—$Y_c$. Small Circles Indicate Munsell Colors for Value 5/.

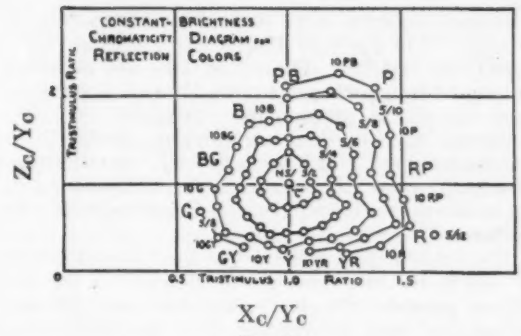


Fig. 11

Adams' Constant Brightness Chromaticity Diagram. I.C.I. Tristimulus Ratios $X_c/Y_c$ Are Plotted Against $Z_c/Y_c$. Small Circles Indicate Munsell Colors for Value 5/.

### Munsell Hue, Value/Chroma

In 1940 data on color chips in the twenty-hue edition of the Munsell *Book of Color (30)* were published *(11)*. This was a result of work done on a bachelor's thesis by Glenn and Killian in 1935 at the Massachusetts Institute of Technology. In a preliminary report of an O.S.A. subcommittee on the spacing of the Munsell colors, preliminary smoothed curves *(32)* based on the Glenn-Killian data were included. Not until 1943 were the final smoothed charts made available by the subcommittee *(31)*, with I.C.I. $(x,y)$-data for preparing diagrams extrapolated to the theoretical limit *(23)* for nonfluorescing surface colors. These are based on additional data on the Munsell colors from the National Bureau of Standards *(21)* and the Interchemical Research Laboratories *(13)* and on a very large number of judgments (over three million) made by observers who systematically examined the constant-hue and constant-value charts of the standard library edition. Table I of the subcommittee's report *(31)*, is a 9-page table that provides I.C.I. ($Y$ and $x$, $y$) equivalents of the recommended Munsell notations for forty hues and nine values at every second chroma step from zero to the pigment maximum. This table can be used by anyone, anywhere, to construct large-scale diagrams for converting I.C.I. data to Munsell hue, value, and chroma renotations. The hue and chroma loci for value 5/ are shown in Fig. 15.

The term renotation is used to distinguish the ideal Munsell notation, as smoothed and recommended by the subcommittee, from the actual or book notation of the Munsell samples. Book notations vary somewhat from the ideal or renotations, usually by a tolerance small enough to be of no significance in the preparation of teaching charts but large enough so that book notations must be distinguished from renotations in any small-difference work that involves direct comparison to samples in the Munsell book.

Diagrams of the most useful portion of the I.C.I.

—Munsell charts were published for values 1/ through 9/ in the July 1943 *Journal of the Optical Society of America.* These diagrams are obtainable in larger form, packaged by the Munsell Color Company for use as graph paper. Complete I.C.I. diagrams for each of these value levels, similar to the one shown in Fig. 15 for value 5/, are illustrated in a publication *(33)* that may be obtained on request from the United States Department of Agriculture.

The outstanding usefulness of the Munsell system, its simple notation, and its charts, lies in the fact that it provides the best illustration of "uniform chomaticity" that is available. It is not perfect, but it is entirely practical for use in both laboratory and shop. By means of its simple notation of hue, value, and croma (*H V/C*) the layman, after a very brief explanation *(29, 33, 34)*, can visualize the color that is specified, and the scientist, by translating his instrument readings to the Munsell notation can understand what his results mean in terms of color. If necessary all this can be done by means of diagrams without reference to Munsell charts. This understanding is not possible in terms of I.C.I. or of dominant wavelength and purity, or of any other diagram or notation of nonuniform chromaticity.

Prior to 1943 a scientist accepted his instrument readings—unless they were so very far off that he knew something was wrong, as with fluorescent and bronzy samples—without visualizing what they specified. Today, when by use of the Munsell notation the scientist studies small differences, he has a means by which he can decide how large his color difference really is. Furthermore, by use of the Munsell color charts in direct visual comparisons, one has the simplest possible means of transplanting from one system into another. This is why so many of the present day comparisons are being made through the Munsell notation.

It is really quite as necessary to have an accurate visual Munsell notation of a sample as it is to have an accurate spectrophotometric curve. Either, by itself, may be misleading, since such factors as fluorescence, gloss, and color of illuminant may affect either result unless conditions of measurement are standardized. However, given a Munsell chart and a little skill at comparison by means of masks of standard backgrounds, and one may do a great deal of very simple and direct visual colorimetry. For example, the simplest way to obtain an approximate I.C.I. notation of a sample is to compare it with the Munsell charts, obtain its book notation, look this up in the tables and charts published for measurements

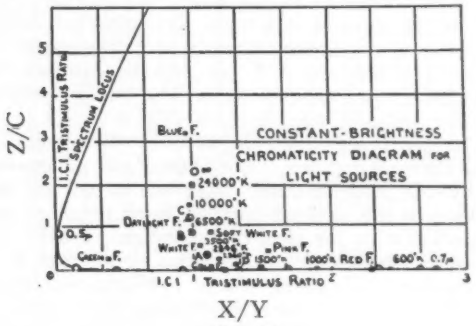


Fig. 12

**Adams' Constant Brightness Chromaticity Diagram (X/Y Against Z/Y), Showing a Portion of the Spectrum and Black Body Locus, Plus Points Representing a Number of Fluorescent Lamps.**

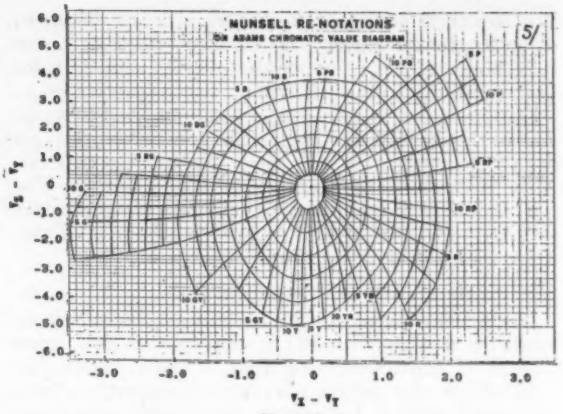


Fig. 13

**Adams' Chromatic-Value Diagram. $V_x$—$V_T$ Plotted Against $V_z$—$V_T$, the Neutral Point at the Center, or Origin. Munsell Renotations for Surface Colors Extrapolated to the Theoretical Limits Are Plotted on This Diagram.**

of Munsell colors *(11, 21, 13)*, and obtain the I.C.I. specification that corresponds to this Munsell book notation. To change book notations to re-notations, consult Table III of the 1943 O.S.A. subcommittee reports (pages 408 to 414, *Optical Soc. Amer. Jour.* 33), or follow the directions given in that report *(31)* for obtaining Munsell re-notations from I.C.I. and the reverse.

An index file list of all Munsell papers published since 1929, including repaints, with all available I.C.I. data published or unpublished, including the Munsell re-notation based on each such measurement, has been assembled by Nickerson and Bellamy. It is intended to publish this 130-page index.

## ISCC-NBS Method of Designating Colors

For conversion to a standard method of designating colors by word description, the ISCC-NBS system, developed under auspices of the Inter-Society Color Council and the National Bureau of Standards, is available. It was one of the first problems studied by the Council, an early report by Godlove being the basis on which the American Pharmaceutical Association, for the U. S. Pharmacopoeia and National Formulary, stationed K. L. Kelly at the National Bureau of Standards as a research associate. In 1939 Judd and Kelly *(20)* published a description of this system of color designations.

To obtain the ISCC-NBS designation for a color one must first obtain its Munsell notation. This may be done either by direct visual comparison, under standard conditions defined in the report, with charts of the Munsell book, or by conversion through I.C.I. data, first to Munsell re-notation, then to book notation.

Since each designation covers a large block of distinguishable colors in the color solid, there may be less color difference between two samples of different names that lie close to a common boundary than between samples which lie within the same block but close to opposite boundaries. The limits are needed for converting color data to these color names but in addition, for visualizing the difference between the centers of each name block, the central notations for each block have been worked out and published *(35)*. Figure 16 shows the relation of adjective modifiers used in the ISCC-NBS method. Figure 17 illustrates the type of chart on which Judd and Kelly report boundaries for the color names.

An extension of these names, to describe the color

of lights, has been made by Kelly *(20a)*. The chromaticity limits are indicated in Fig. 18 in terms of the I.C.I. *x,y*-diagram.

### Ostwald Hue, White Content, Black Content

In 1942 a series of color chips representing the Ostwald color system *(18)* was published by the Container Corporation of America, Color Laboratories Division, in accordance with certain principles developed in an analysis of the Ostwald color system that was later published by Foss, Nickerson, and Granville *(8)*.

While other editions of Ostwald color chips are available *(38)*,* no other has been systematically measured in I.C.I. terms, although a great deal of work was done in Germany prior to 1931, with studies published regarding the Ostwald system in trichromatic coordinates. See particularly references 37 and 38 of *(8)*. As far as is known, the analysis in the Foss, Nickerson, and Granville paper *(8)* is the only available thorough treatment of Ostwald theory in I.C.I. terms. It includes measurements of three sets of original Ostwald color chips in the *pa* series, and the entire series for two pairs of triangles.

Publishers of the *Color Harmony Manual* were among the first to realize the practical advantage of having I.C.I. data available so that the colors of their charts might be translated to other terms and thus be available for wider use.

The 680 chips of the *Color Harmony Manual* were prepared by applying a pigmented film of appropriate color to a base of clear transparent cellulose acetate. The pigment side possesses a matte surface, the film side is glossy. Colorimetric specifications for the dull side of these chips were published in 1944 in a 5-page table by Granville and Jacobson *(12)*. I.C.I. ($X$, $Y$, $Z$, $x$, $y$, $z$) and dominant wave length and purity specifications are included; they are based on spectrophotometric measurements made on 2¾ by 3¾ inch samples, most of them at the Electrical Testing Laboratories (Report No. 306699).

For a further understanding of the color relations in these charts, Munsell re-notations have been converted from the published I.C.I. specifications. There has been no rigid visual comparison of these data (as was done by Reimann, Judd, and Keegan for the TCCA standards), but since measurements apply only to the matte side of the chips it is probable that calculated and visual notations should agree. The data, as spot-checked, are presented in Table I for hues 1 to 24 of the *Color Harmony Manual*. The neutrals are as follows:

Ostwald a = Munsell $N$ 9.5/($Y$ 0.4)
Ostwald c = Munsell $N$ 7.9/($BG$ 0.1)
Ostwald e = Munsell $N$ 6.4/($G$ 0.1)
Ostwald g = Munsell $N$ 5.2/($B$ 0.1)
Ostwald i = Munsell $N$ 4.1/($GY$ 0.1)
Ostwald l = Munsell $N$ 3.5/
Ostwald n = Munsell $N$ 2.7/
Ostwald p = Munsell $N$ 2.1/($Y$ 0.1)

Technically Munsell neutral *(N)* indicates only colors with 0.0 chroma, but because this would not allow the gray series to be easily identified and segregated, the near-neutrals (usually considered as chromas under 0.5) are indicated as $N$ and the chroma, accompanied by the nearest of the 10 principal hue names, is placed in parenthesis after the solidus (/) which follows the value number.

One word of caution should be made in presenting these as Ostwald data. It must be remembered that they are renotations (not book notations), that they apply only to the chips in the *1942 Color Harmony Manual*, and only to the dull side of those chips.

### TCCA Standards

The color cards of the Textile Color Card Association of the United States, Inc., are widely used in the textile and allied industries. The specification of the colors of the Ninth Edition Standard Color Card and the United States Army Color Card was undertaken at the National Bureau of Standards for the purpose of correlating these textile standards with American War Standard Z44-1942 for the specification and description of color. The Textile Color Card Association of the United States, Inc., provided a research associateship at the National Bureau of Standards to make this possible. As a result, a very fine piece of practical research in color was published in 1946 *(39)*.

In accord with requirements of the four-part provision of the ASA standard *(4)*, spectrophotometric curves, I.C.I. data, Munsell notations, and ISCC-NBS names were obtained for each sample. The reliability of the adopted values was established by detailed cross-checks and a closing check under conditions of use. The TCCA standards comprise the first extensive series of material color standards to receive a calibration thus cross-checked in detail.

Measurements were made on the recording spectrophotometer, multipurpose reflectometer, chromaticity-difference colorimeter, Macbeth-Martens reflectometer, and by visual judgment of Munsell book notations. It is this use of the Munsell notation that is so important in colorimetry, for in this study no colorimetric values were adopted until those values were known, by observation, to be sensible values—values that could be accepted when the samples were examined under the usual conditions of daylight illumination. The report is thus a major contribution to colorimetry; the authors knew the color meaning of their published results. They measured the samples with available instruments, then made visual estimations of the Munsell book notations of the samples under natural diffuse daylight, and compared the results. They found it possible to reduce the data in a systematic way that yielded no important discrepancy between instrumental result and visual estimate. Table V of their report *(39)* comprises 4½ pages of closely printed material. Adopted color specifications are listed in the order of TCCA cable number, TCCA name, I.C.I. ($Y$, $x$, $y$)-specification, Munsell re-notation and book notation, and the ISCC-NBS color designation.

### Maerz and Paul Dictionary of Color

This book by Maerz and Paul *(26)* was published in 1930. It includes in its 56 charts, 7,056 color samples, and has a very useful text of 73 pages. It is the best authority available for use as a dictionary of color names, that being the purpose for which it was published. The charts were printed and then matched to chips representing color names of various standard charts. Thus, this dictionary in itself interrelates names of certain of the many color samples that have appeared in books, portfolios, and cards proposing various color names.

No textile names other than those recommended by the Textile Color Card Association are included for the period following 1916. For colors other than those found in Ridgeway or the Textile Color cards, and which appear in the Funk and Wagnalls' New

* See also bibliography of Foss, Nickerson, and Granville *(8)* for list of several original Ostwald publications; none now available as far as can be ascertained, although Ostwald's business was kept up by his daughter until the time of World War II.

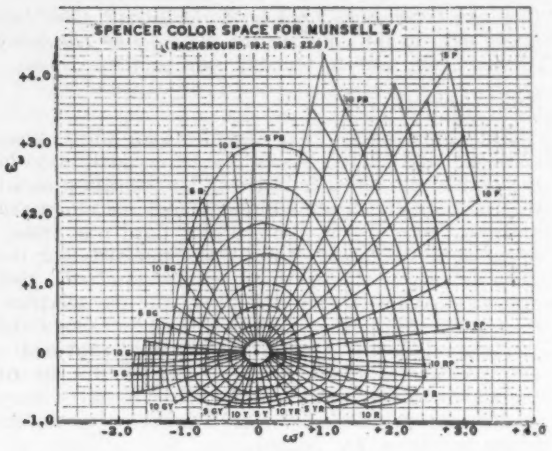


FIG. 14

**Moon and Spencer Omega Space Showing a Plot of Munsell Renotations for Surface Colors Extrapolated to the Theoretical Limits.**

Standard Dictionary, the standards of Maerz and Paul agree with that work, including all common names, many textile names, many paint names, and some miscellaneous names. Use of this material by Maerz and Paul was through courtesy of Dr. F. H. Vizetelly, managing editor of the New Standard Dictionary, who analyzed over 6,000 color samples on Maxwell disks. Samples for each given name were analyzed, and the average disk measurement was considered to represent general usage regarding that name. The work was done at the Physics Department of Columbia University, under Professor William Hallock, and the analyzing disks loaned to the authors of the Maerz and Paul Color Dictionary so that they might reproduce, under identical conditions, the colors as listed. Ridgway names which used such terms as light, pale, dark, and deep, are excluded from the Dictionary, since these words are necessary for indication of more or less indefinite degrees of value for which there are no other words to take their place.

Some use of the colors on these charts has been made in setting standards for canned fruits and vegetables in the United States Department of Agriculture, not because other methods are not perferable, but because the simplest kind of color work is color matching, and for that purpose a very large number of color samples is necessary. A much more useful method is that of color interpolation between samples equally spaced on the Munsell charts. When such interpolation seems too difficult or uncertain, the Maerz and Paul Color Dictionary, having in it over 7,000 color samples, is the best thing to recommend. In order to make the charts more useful, conversions to Munsell notations were made in the laboratories of the United States Department of Agriculture several years ago of the first 20 of the 56 charts in the book.*

A set of Maerz and Paul charts was cut up, each line of each chart cut into two pieces of six samples each, and the two pieces hinged on to a 3 by 5 inch card. Thus all samples on line 1 of plate 1 were on one card, those on line 2 were on a second card, and so on. A three-holed mask of neutral gray was used for comparison, with one color sample at a time placed behind the center hole of the mask. Charts of the pocket-edition Munsell *Book of Color* were used for comparison, the two nearest hue charts being selected, each moved behind the other two holes in the mask until the nearest Munsell color chips appeared. A judgment of the closest Munsell notation was made by interpolation to the nearest 0.5 hue, 0.1 value, and 0.1 chroma. After an entire Maerz and Paul chart was completed by independent judgments, the notations were compared. Comparisons were made under standard conditions of artificial daylighting, about 60 foot candles, Macbeth 7500°K. The Munsell notations thus obtained are given in Table II.

It was intended at the time the work was done that the 56 plates would be completed, but since the first 20 charts contain most of the red-to-green colors in which there was particular interest, this has not yet been done.

Some smoothing was attempted, since it is probable that variations in printing from book to book would be the cause of some irregularities, and charts made up for this purpose indicate how crowded the colors are in some portions of the charts, and how separated they are in other portions. This is a logical outcome of the method used in producing these charts by screen printing.

For comparative purposes, and to make a check of color specifications obtained visually against those obtained by calculation from spectrophotometric curves in this color range for printed colors, Keith F. Stultz while with the Engineer Board at Fort Belvoir, Va., measured a selected series of samples from each of the first nine Maerz and Paul charts, by using the samples that had been visually matched several years before. The samples were measured as near the center as possible, with a diaphragm placed in the spectrophotometer before the beams are split at the second prism. Samples were backed with black, the specular component was excluded, and fresh white oxides were used in the measurement. Calculations *(22)* of I.C.I. data by the weighted ordinate method were obtained

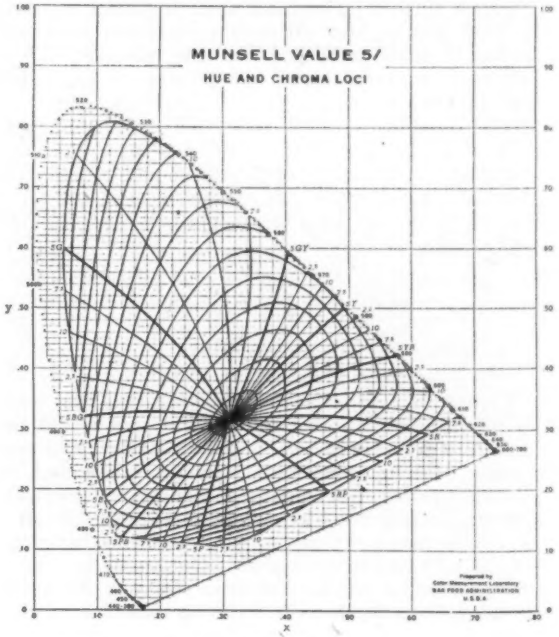


FIG. 15

**Hue and Chroma Loci for Munsell Renotations for Value 5/ as Recommended by O.S.A. Subcommittee (31).**

* Several years ago Dr. I. H. Godlove and Mrs. Genevieve Reimann, during the course of work on color terms for the 1935 revision of Webster's New International Dictionary, visually obtained Maerz and Paul and Munsell notations for a great many color names.

by I.B.M. procedures (progressive digiting). These were transformed by use of Munsell—I.C.I. conversion charts to Munsell re-notations and are contained in Table III.

Before attempting to cross-check these too closely, it should be remembered that the colors are printed samples with a semigloss surface, that the visual judgments are in terms of book notation while the data based on spectrophotometric measurements are in renotations, and that the visual judgments were made several years before the spectrophotometric measurements. It is also probable that the bronze effect on certain of the darker samples is better compensated for visually than by the spectrophotometer. In making a careful cross-check, all of these matters must be taken into consideration. But for an over-all comparison of what may be expected of visual versus spectrophotometric measurements on a first try on printed samples, these data seem to present a fair sample and are listed in order to illustrate this point. Of the two sets of data, the visual results are those we use. On the average, except for extrapolated notations, these visual results should be correct—for the conditions of observation used—well within the visual tolerance found some time ago between two observers*: 0.6 hue, 0.2 value, and 0.3 chroma.

### Ridgway Color Dictionary

The primary purpose of the Ridgway charts *(40)* was to establish meaning for color names for use in the natural sciences. These charts were first developed in 1886, and enlarged in 1912, by Robert Ridgway of the United States Biological Survey, with the help of A. Hoen and Company of Baltimore, who now sell this publication. The charts contain 1,113 colors. These consist of 36 hues, each reduced in disk mixture by regular proportions of white, gray, and black to give systematic groupings. The first group of charts represents what Ridgway called "tints" and "shades" of his 36 full colors and the groups that follow represent "tints" and "shades" of "broken colors," the term used for full colors reduced with a definite amount of neutral gray. To each color on the charts Ridgway gave a name.

Unfortunately, no thorough study has been made of the Ridgway colors either by spectrophotometric analysis or by direct visual comparison with the Munsell charts. Therefore, neither I.C.I. nor Munsell specifications are available for converting Ridgway names to any other specification. A few measurements have been made by William H. Beck, of Baltimore, Md., in connection with philatelic discussions of the color of the United States 3-cent pink stamp of 1861, and the 1-cent blue stamp of 1851 to 1857. In the first case a group of 29 pinks from the Ridgway book were spectrophotometered at the Electrical Testing Laboratories, and colorimetric data calculated by Mr. Beck. In the second case 12 Ridgway blues were handled in the same way. He has also made a visual conversion to Munsell notations, but since this was done in a rather casual manner, and not under standard conditions, we have not included the information.†

### Lovibond Glasses

The Lovibond tintometer was invented in England in 1884 for measuring color in the brewing industry. By 1896 their series of red, yellow, and blue glasses were in regular use. Each series is intended to be additive, that is, number 3.0 should equal three slides of number 1.0, or one of 2.0 plus one of 1.0, but this is not strictly so. Furthermore, multiple reflections also interefere with the additivity and make it preferable to use combinations of the fewest numbers of glasses. Because Lovibond glasses are widely used in grading oils, and in order to set up a standardized scale against which other sets may be calibrated, spectrophotometric measurements have been made for many of the glasses, particularly at the National Bureau of Standards, by Gibson, Haupt, and others *(9, 10, 14)*. A network diagram of such filters referred to the I.C.I. $(x, y)$-diagram for illuminants A and C, is now published* by the National Bureau of Standards. Tintometer, Ltd., manufacturers of the glasses, have cooperated in the test work and have published several reports in England *(46, 7)*. For the best brief description of these glasses, including their shortcomings as well as good points, see section 7 of the O.S.A. Colorimetry Committee's report on colorimeters and color standards *(37)*. In connection with a thesis for his doctorate, S. B. Detwiler, Jr., † several years ago developed a network for I.C.I. il-

TABLE III.—MAERZ AND PAUL SAMPLES, CONVERTED TO MUNSELL RE-NOTATIONS FROM SPECTRO-PHOTOMETRIC MEASUREMENTS

| No. | A | D | H | L |
|---|---|---|---|---|
| | **Maerz and Paul—Plate 1** | | | |
| 1 | 10 YR8.9/ 0.8 | 4 R8.0/ 3.6 | 1 R7.1/ 6.3 | 3.5 R4.9/13.9 |
| 4 | 6.5RP7.0/ 8.0 | 8 RP6.5/ 9.5 | 9 RP5.8/10.7 | 3.5 R4.6/13.9 |
| 6 | 6 RP5.2/15.8 | 8 RP4.9/15.4 | 9.5RP4.8/15.1 | 4.5 R4.6/14.1 |
| 7 | 10 YR9.1/ 0.8 | 4.5 R8.1/ 3.2 | 10 RP7.1/ 6.2 | 3 R5.0/13.6 |
| 10 | 10 R7.6/ 6.4 | 7.5 R6.9/ 7.9 | 6 R6.3/ 9.5 | 6 R4.9/13.8 |
| 12 | 2 YR6.4/13.4 | 10 R6.0/13.2 | 9 R5.5/13.6 | ..... |
| | **Maerz and Paul—Plate 2** | | | |
| 1 | 5 Y8.7/ 0.7 | 4 R7.8/ 3.4 | 1 R7.0/ 6.0 | 3 R5.0/12.8 |
| 4 | 7 RP6.9/ 7.8 | 8 RP6.4/ 9.2 | 8 RP5.9/ 9.9 | 3 R4.6/13.2 |
| 6 | 6 RP5.1/14.8 | 7.5RP5.0/14.6 | 9 RP4.9/14.5 | 3.5 R4.4/13.4 |
| 7 | 2.5 Y8.8/ 0.9 | 5 R7.9/ 3.0 | 1 R7.0/ 5.6 | 2.5 R5.0/12.5 |
| 10 | 1.5YR7.4/ 6.1 | 8.5 R6.8/ 7.3 | 7 R6.2/ 8.8 | 6 R4.8/13.5 |
| 12 | 2 YR6.3/12.6 | 1 YR5.9/12.4 | 9.5 R5.5/12.5 | ..... |
| | **Maerz and Paul—Plate 3** | | | |
| 1 | 5 Y7.6/ 0.9 | 7 R7.0/ 3.0 | 2.5 R6.1/ 5.3 | 4.5 R4.4/11.8 |
| 4 | 7.5RP6.1/ 6.9 | 8.5RP5.6/ 8.2 | 9.5RP5.1/ 8.6 | 4.5 R4.1/11.3 |
| 6 | 6 RP4.8/12.9 | 7.5RP4.6/12.7 | 0.5 R4.4/12.0 | 4.5 R4.0/11.6 |
| 7 | 5 Y7.7/ 1.0 | 8.5 R7.0/ 2.5 | 2.5 R6.2/ 5.0 | 3.5 R4.4/11.0 |
| 10 | 2.5YR6.5/ 5.6 | 9.5 R5.9/ 6.8 | 7.5 R5.4/ 7.7 | 6.5 R4.3/11.2 |
| 12 | 2.5YR5.6/10.6 | 1.5YR5.2/10.3 | 10 R4.9/10.3 | ..... |
| | **Maerz and Paul—Plate 4** | | | |
| 1 | 5 Y6.8/ 0.8 | 10 R6.3/ 1.8 | 4 R5.9/ 3.3 | 4 R4.1/ 9.2 |
| 4 | 8.5RP5.4/ 5.8 | 9 RP5.1/ 6.5 | 8.5RP5.0/ 6.6 | 4 R3.9/ 9.2 |
| 6 | 6.5RP4.3/10.8 | 8 RP4.1/10.6 | 8.5RP4.2/10.4 | 4.5 R3.8/ 9.2 |
| 7 | 5 Y6.8/ 1.0 | 2.5YR6.3/ 1.6 | 4.5 R6.0/ 3.0 | 3 R4.0/ 8.7 |
| 10 | 3.5YR5.9/ 4.5 | 1 YR5.6/ 4.8 | 9 R5.3/ 5.5 | 7 R3.8/ 8.9 |
| 12 | 3.5YR5.1/ 8.3 | 3 YR4.9/ 8.2 | 1.5YR4.7/ 8.3 | ..... |
| | **Maerz and Paul—Plate 5** | | | |
| 1 | 5 Y6.0/ 0.9 | 2 YR5.5/ 2.0 | 6.5 R5.1/ 3.8 | 5.5 R3.9/ 8.0 |
| 4 | 1.5 R5.0/ 4.6 | 2 R4.7/ 5.3 | 2.5 R4.4/ 5.9 | 4 R3.7/ 8.8 |
| 6 | 8 RP4.0/ 8.9 | 9.5RP3.8/ 8.9 | 1.5 R3.8/ 8.6 | 5.5 R3.5/ 8.3 |
| 7 | 5 Y6.1/ 1.0 | 2 YR5.5/ 2.0 | 6 R5.0/ 3.6 | 5.5 R3.9/ 7.8 |
| 10 | 4 YR5.4/ 4.3 | 1 YR5.0/ 4.8 | 9 R4.7/ 5.6 | 7 R3.8/ 8.0 |
| 12 | 3.5YR4.7/ 7.4 | 2.5YR4.5/ 7.2 | 1 YR4.1/ 7.1 | ..... |
| | **Maerz and Paul—Plate 6** | | | |
| 1 | 3 Y5.2/ 0.7 | 0.5YR4.9/ 1.8 | 6 R4.6/ 2.9 | 4 R3.7/ 6.3 |
| 4 | 1 R4.4/ 4.1 | 2.5 R4.2/ 4.7 | 2 R4.1/ 4.8 | 5 R3.5/ 6.3 |
| 6 | 8 RP3.6/ 7.6 | 0.5 R3.5/ 7.3 | 1 R3.5/ 7.3 | 5 R3.4/ 6.6 |
| 7 | 5 Y5.4/ 0.7 | 1 YR4.9/ 1.7 | 4.5 R4.6/ 3.1 | 4 R3.7/ 6.0 |
| 10 | 3.5YR4.7/ 3.5 | 1 YR4.5/ 3.9 | 10 R4.3/ 4.4 | 7.5 R3.6/ 6.2 |
| 12 | 4 YR4.2/ 5.9 | 3 YR4.0/ 5.8 | 1.5YR3.8/ 5.7 | ..... |
| | **Maerz and Paul—Plate 7** | | | |
| 1 | 5 Y4.2/ 0.6 | ..... | 10 R3.9/ 2.2 | 7.5 R3.2/ 3.9 |
| 4 | 4 R3.8/ 2.4 | ..... | 6.5 R3.5/ 3.3 | 8 R3.2/ 4.5 |
| 6 | 1 R3.2/ 4.1 | ..... | 5.5 R3.2/ 4.5 | 4.5 R3.0/ 4.2 |
| 7 | 5 Y4.4/ 0.7 | ..... | 10 R3.9/ 2.1 | 9 R3.3/ 4.0 |
| 10 | 8 YR4.0/ 2.0 | ..... | 2.5YR3.7/ 3.0 | 1 YR3.3/ 3.9 |
| 12 | 7 YR3.7/ 3.6 | ..... | 4.5YR3.4/ 3.7 | ..... |
| | **Maerz and Paul—Plate 8** | | | |
| 1 | 10 YR3.1/ 0.3 | ..... | 6.5YR3.0/ 1.0 | 7.5YR2.8/ 1.8 |
| 4 | 8.5YR3.0/ 1.0 | ..... | 8.5YR2.9/ 2.6 | 8 YR2.8/ 2.1 |
| 6 | 7 YR2.6/ 1.5 | ..... | 9.5YR2.6/ 1.8 | 5 YR2.8/ 2.0 |
| 7 | 7.5YR3.1/ 0.3 | ..... | 9 YR2.9/ 1.0 | 6.5YR2.9/ 1.8 |
| 10 | 2.5 Y3.1/ 0.9 | ..... | 10 YR3.0/ 1.4 | 6.5YR2.8/ 1.9 |
| 12 | 4 Y3.1/ 1.5 | ..... | 2.5 Y3.0/ 1.7 | ..... |

* Nickerson and Kelly, in making visual color observations of 250 soil color samples.

† Recent information indicates that in the Department of Botany, University of Toronto, D. H. Hamly and W. I. Illman have obtained Munsell notations for a majority of Ridgway samples.

* Haupt, G. W., and Douglas, F. L., Chromasticities of Lovibond Glasses, *Opt. Soc. Am. J.* 37, 698-706 (1947).

† Bureau of Agricultural and Industrial Chemistry, U.S.D.A. unpublished manuscript.

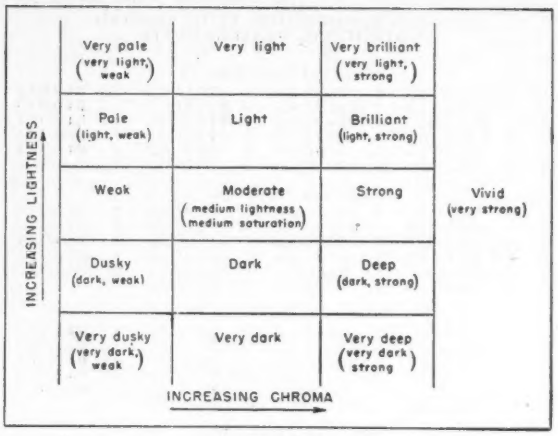


**Fig. 16**
**Relation of Adjective Modifiers for the ISCC-NBS Method of Designating Colors.**

luminant C based on spectrophotometric measurements of 9 yellow and 28 red glasses.

Use of more than two of the three color series of the Lovibond system precludes use of any single chart to convert to I.C.I. Therefore, in order to allow conversion from Lovibond to I.C.I. the Lovibond-Schofield system was developed. In it only two of the three series of glasses are used at one time in matching a color. On this basis, trichromatic coordinates have been computed for illuminant B and are plotted on the Judd U.C.S. basis, as illustrated in a small-scale diagram in *Colorimetry*, a booklet put out by Tintometer, Ltd. *(46)*. Correspondence with them in 1943 revealed that graphs for C, as well as B illuminant, had been made on metal, 24 by 24 inches, but because of export controls these graphs were not then available for shipment.

### Wratten Filters

Wratten filters of specially purified dyes in gelatin films have been used in photography and in scientific work since 1907. They are made available by the Eastman Kodak Company, and are fully described in their booklet, Wrattan Light Filters. In 1945 Dr. MacAdam *(25)* published colorimetric specifications for these filters in terms of I.C.I. ($X$, $Y$, $Z$, $x$, $y$), and dominant wave length and purity, based on spectral transmittance values, for I.C.I. illuminants A and C, and for an artificial daylight source consisting of a tungsten filament lamp operated at 2360°K, filtered through Wratten No. 78. The data for A and C illuminants are plotted on ($x$, $y$)-diagrams, so that their color distribution is immediately evident.

## 3. Tolerance Specifications Related to Systems of Color Specifications

One reason for measuring and specifying color, and for the searching that goes on to find uniform chromaticity scales and uniformly spaced color solids, is the commercially important problem of setting color tolerance specifications.

Successful establishment of specifications for color tolerance depends to a very considerable extent upon two things, first, the ability to measure accurately differences as small as the trained eye can detect, and, second, the language of the specification.

The eye is capable of detecting very small color differences. No instrument, as it is usually operated today, is able to compete with the unaided normal eye in detecting small hue and chroma differences, particularly on samples that are fairly nonselective. Small value differences, on the other hand, may be more precisely detected by use of a good photometer, whether it is used as an aid to the eye in making visual judgments or whether it is photoelectrically operated.

These facts should be understood and accepted, for it cannot be expected that color tolerance specifications may be met to any closer tolerance than is provided by the instrument or method on which the measurements are made. Too often the instrument tolerance is not known. Even when it is known in a single laboratory, it is seldom known for similar instruments in different laboratories.

To go back to the shiny red handbags: If several laboratories measure the same purse on well-standardized equipment, and the difference between the results is 1.5 Munsell hue steps, 0.1 of a value step, and 0.8 of a chroma step, then certainly if the tolerance is to be judged by instrument measurement it will not be useful to set a tolerance any closer than about twice these amounts. Yet, if they are set that large, the variation among handbags on a counter could be detected easily by the customer.

The paper industry—and other industries as well—has a problem in grading near-whites. Brightness is a factor that can be measured, particularly at a single wave length as is done in the paper trade. But paper brightness is not equivalent to the visual lightness, or Munsell value of a sample. As for setting tolerances of hue and chroma for near-whites that can be met by instrument measurement, this is something that the industry still waits to see. While the eye sees such differences, there are individual variations and inconsistencies that are drawbacks to complete dependence on visual work; therefore, the search goes on for instrumental methods. No doubt as the reasons for these difficulties become more widely recognized, special instrumental means will be developed for the detection of small color differences. There is much to be said on the subject. It would take another day to discuss the problem fully, and since it is not my

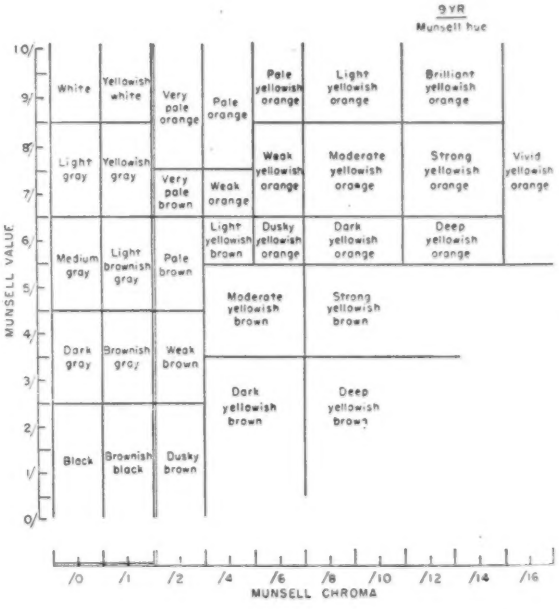


**Fig. 17**
**Typical Boundary Chart for ISCC-NBS Color Names as Given in Judd-Kelly Report (20).**

TABLE IV.—TENTATIVE LIMITS FOR THREE DEGREES OF COLOR TOLERANCE, IN TERMS OF H/V/C AND TOTAL INDEX I

| Identification | Limits for Hue | Value | Chroma | I |
|---|---|---|---|---|
| AAA | 2/C | 0.05/ | /0.2 | 1.4 |
| AA | 3/C | 0.10/ | /0.4 | 2.4 |
| A | 4/C | 0.20/ | /0.6 | 3.7 |

province to discuss instruments, I shall have to leave the subject for others to discuss at some future time.

Yet the author must point out in regard to color tolerance specification how necessary it is to know the limitations of any instrument or method of measurement. No matter how great the possibilities of an instrument in other directions, its limitations in accurately measuring small color differences must be understood if color tolerances are to be specified in terms of small differences.

In the report of a committee appointed to make recommendations regarding color tolerance to the Munsell Color Foundation, Dr. Judd lists tentative limits for three degrees of tolerances, the total difference not to exceed the indicated unit of tolerance *(1)* (Defined in Table V, on page 35). These are given in Table IV. Conformity to the AAA tolerance requires test methods that involve direct comparison to material standards. No known instrument, under usual methods of operation, will allow one to measure and meet this very strict tolerance. Yet it is a tolerance that the eye detects without difficulty. The AA tolerance need not involve a match to material standards but can be tested by accurate methods of indirect instrumental readings. The word accurate should be emphasized. The A tolerances are meant for work papers that under no circumstances may be designated as standards.

This material on size of tolerance is included in order to provide some idea of what may be considered a series of strict to fairly loose tolerances. To meet such specifications one must select a measurement method of suitable accuracy.

Now assume that the methods of measurement and calculation are of suitable accuracy. There still remains the problem of specification. In what terms may the tolerance best be expressed?

Any general expression for small color difference that is to be satisfactorily developed must be based on equality of color difference throughout color space. For that reason, the many methods that may serve for individual cases, or for restricted groups of colors, will not serve as a general basis for expressing color differences.

For example, one laboratory dealing in pigments may find that a particular pigment tolerance may be set in terms of the relation and shape of spectrophotometric curves. Yet it is dangerous business to generalize from this experience. Color tolerances for general application cannot be satisfactorily set in such a manner. In another laboratory a satisfactory specification for a particular color may be in terms of departure of $Y$, $x$ and $y$ from a given figure. Again, while this may prove satisfactory for a particular case, it is entirely unsatisfactory to use as a general method for setting a color tolerance figure.

To be generally applicable a formula for small color differences must be based on some form of color space that bears at least a reasonable approximation to psychologically equally stepped scales—in other words, to some basis of providing uniform chromaticity and lightness scales.

A complete tolerance specification must take into consideration factors of transparency, gloss, luster, but it seems enough at present to limit ourselves to attributes of color perception, hue, lightness, and saturation and their psychophysical correlates.*

Several formulas for general use have been developed. These are "small-difference" rather than "tolerance" formulas since in setting the size of a tolerance the purpose, as well as other related factors, must be taken into consideration.

Two sessions of the Inter-Society Color Council already have been devoted to a discussion of this subject, one in 1939 in cooperation with the American Psychological Association *(16)*, the other in 1944, a discussion session on Small Color Differences jointly sponsored by the American Association of Textile Chemists and Colorists and the Federation of Paint and Varnish Production Clubs *(17)*. At the latter meeting a summary of available information on small color difference formulas was included. Table V is taken from that summary. It includes two formulas based on Munsell space, two on Judd's U.C.S. diagram with a scale of lightness added, one on Adams' chromatic-value space, and on Adams' chromatic-valence, or second chromance space.

An extended discussion of the problem, with a full list of references, and the application of these several formulas to 201 samples representative of 11 groups of colors used for camouflage purposes, including 9

* A definition of color terms may be found in The Concept of Color, Fig. 3, O.S.A. Colorimetry Committee Report, *Optical Soc. Amer. J.* 33, p. 552 (1943).

TABLE V.—SMALL COLOR DIFFERENCE FORMULAS FOR USE IN EXPRESSING COLOR TOLERANCES, COLOR FADING, ETC.

| Author | Symbol and Formula | Type of Color Space on which Formula is Based |
|---|---|---|
| Nickerson | $I = \frac{C}{5}(2\Delta H) + 6\Delta V + 3\Delta C$ | Munsell 3-dimensional concept of hue, value, and chroma ($H$-$V$/$C$) |
| Nickerson-Balinkin | $I' = [(\frac{C}{5}2\Delta H)^2 + (6\Delta V)^2 + (20/\pi\Delta C)^2]^{1/2}$ | Do. |
| Judd | $\Delta E_J = f_s([7Y^{1/6}[(\Delta\alpha)^2 + (\Delta\beta)^2]^{1/2}.10^2]^2 + [k\Delta(Y^{1/2})]^2)^{1/2}$ when $\alpha = \frac{2.4266x - 1.3631y - 0.3214}{1.0000x + 2.2633y + 1.1054}$, $\beta = \frac{0.5710x + 1.2447y - 0.5708}{1.0000x + 2.2633y + 1.1054}$, $f_s = 1.0$ for matte surfaces, $k = 100$ | 3-dimensional concept combining Judd UCS diagram with a scale of lightness, ($L = Y^{1/2}$) |
| Judd-Hunter-Scofield | $\Delta E_{H-S} = \sqrt{(L_1 - L_0)^2 + (a_1 - a_0)^2 + (b_1 - b_0)^2}$ when $L = 100\sqrt{Y}$, $a = 7L\alpha$, $b = 7L\beta$, and $\alpha$ and $\beta$ are the same as in the Judd formula | Do. |
| Adams "Chromatic Value" | $\Delta E_A' = f[(k\Delta V)^2 + [\Delta(V_X - V_Y)]^2 + [0.4\Delta(V_Z - V_Y)]^2]^{1/2}$ when $k = 0.23$ | 3-dimensional concept in which the coordinates are $V_Y$, $(V_X - V_Y)$ and $(V_Z - V_Y)$, $V$ being Munsell value |
| Adams "Chromatic Valence" | $\Delta E_A'' = f[(k\Delta V)^2 + \Delta(W_X)^2 + (0.4\Delta W_Z)^2]^{1/2}$ when $W_X = [(X_o/Y - 1)]V$, $W_Z = [(Z_o/Y - 1)]V$, $k = 0.5$ | 3-dimensional concept defined by $V_Y$, $[(X_o/Y - 1)]V$, and $[Z_o/Y - 1]V$; $V$ again being Munsell value, and $X$, $Y$, $Z$ the I.C.I. tristimulus values for "C" illuminant |

TABLE VI.—COMPARATIVE RESULTS OF SEVERAL SMALL-DIFFERENCE FORMULAS

Correlation [using coefficient of multiple determination, $R^2$, as a measure] of tolerance indices by 6 formulas against average visual placement of samples by 10 observers

| Color Series No. | By Formula— Nickerson $I$ | Nickerson $I'$ | Judd $\Delta E_J$ | Judd $\Delta E_{H-S}$ | Adams $\Delta E_A'$ | Adams $\Delta E_A''$ |
|---|---|---|---|---|---|---|
| 1 ..... | 0.49 | 0.42 | 0.43 | 0.40 | 0.37 | 0.39 |
| 2 ..... | 0.42 | 0.53 | 0.55 | 0.52 | 0.53 | 0.62 |
| 3 ..... | 0.58 | 0.51 | 0.67 | 0.53 | 0.65 | 0.55 |
| 4 ..... | 0.78 | 0.79 | 0.77 | 0.61 | 0.71 | 0.57 |
| 5 ..... | 0.48 | 0.33 | 0.40 | 0.58 | 0.50 | 0.57 |
| 6 ..... | 0.86 | 0.75 | 0.48 | 0.87 | 0.75 | 0.64 |
| 7 ..... | 0.90 | 0.90 | 0.92 | 0.87 | 0.86 | 0.84 |
| 8 ..... | 0.35 | 0.45 | 0.00 | 0.20 | 0.21 | 0.14 |
| 9 ..... | 0.53 | 0.71 | 0.58 | 0.32 | 0.21 | 0.36 |
| Average | 0.60 | 0.60 | 0.53 | 0.53 | 0.54 | 0.52 |

chromatic colors (covering the color range of soil and foliage) and 2 neutral colors (white and black) was reported to the Optical Society in 1944 *(36)*. These 201 samples were used to investigate how well the small difference formulas in Table V could be applied, how the results would compare with each other, and how much agreement and dependence could be expected from visual observations. I.C.I. and Munsell notations calculated from spectrophotometric measurements are reported in that paper. For the 9 series of chromatic colors, 12 observers visually graded the samples on a scale of 1 (very good match) to 6 (very good match). Correlation results ($P^2$) of these visual observations against hue, value, and chroma averaged 57% for the 9 series ($P^2$ varied from 0.51 to 0.64 by observers, and 0.40 to 0.83 by color groups).

The correlation ($R^2$) of tolerance indices by the six formulas in Table V against average visual placement of samples averaged 0.56. For the formulas based on Munsell space, the average was 0.60, for the Judd space, 0.53, and for the Adams' space 0.54 and 0.52. Details of results for the 9 color series are given in Table VI.

(Unit differences for the Nickerson and Judd formulas are quite similar, but the Adams' units are different. To adjust results for each formula to the same relative size, the unit difference for each formula, in the order given in Table V, must be multiplied by the following factors: 1.16, 1.29, 0.91, 1.10, 41.85, 18.71.)

All six formulas, when applied to the 201 samples in this study, give results that average near the same level, with more difference for certain of the color series than for others. For comparison to these formula results, visual results are given for each of the 9 series ($P^2$ as correlated against hue, value, and chroma) in the order given in Table V: 0.43, 0.42, 0.65, 0.65, 0.53, 0.74, 0.83, 0.40, 0.47.

Since there is no outstanding difference in result between formulas, the amount of work involved in applying them becomes a factor that should be considered. If data are available in Munsell notations, application of the first Munsell formula requires very little work, the second formula not too much more. If I.C.I. $(X, Y, Z)$-data are available, the Adams' "chromatic-value" formula is simple to apply. If data are available in terms of the amber, green, and blue filters of the Hunter reflectometer, the Judd-Hunter-Scofield formula is simple to apply since:

$$\alpha = \frac{A - G}{A + 2G + B} \qquad \beta = \frac{0.4\ (G - B)}{A + 2G + B}$$

The Judd formula requires the greatest amount of computation. In the O.S.A. paper *(36)*, solutions for two samples are worked out in detail for each formula. By following these through one may judge for himself how long it takes to apply each formula.

Because average results obtained by the several formulas do not differ greatly it seems reasonable to suggest that the formula most applicable to avail able instruments or data be used.

The simple form of Munsell formula is based upon the assumption, for usual conditions of observing samples similar to those in the Munsell book, that 1 value step = 2 chroma steps = 3 hue steps at chroma /5. This form is suggested for use until such time as a new Munsell formula can be developd on the basis of adequate experimental data that will provide enough improvement to warrant a change in the present constants. For those who do not find the Munsell formula convenient to use, it is suggested, when I.C.I. data are available, that before going to the considerable work involved in using the Judd type formula they seriously try out one or another of the Adams' formulas, as these provide as good results and require less work to apply to I.C.I. data.

It should be remembered that even if a particular series of samples seems to give results that prove one formula better than another, actually the sample distribution, or accuracy of measurement, may be at fault rather than the formula. Only on the basis of a representative sampling of colors throughout the color solid can final decision be reached regarding the best formula. When sufficient material of this kind is available we should be able to develop a new formula on the basis of statistical methods to produce the highest correlation with visual results. Such a formula could be converted into terms of several specifications, so that the most convenient might be used in any particular problem.

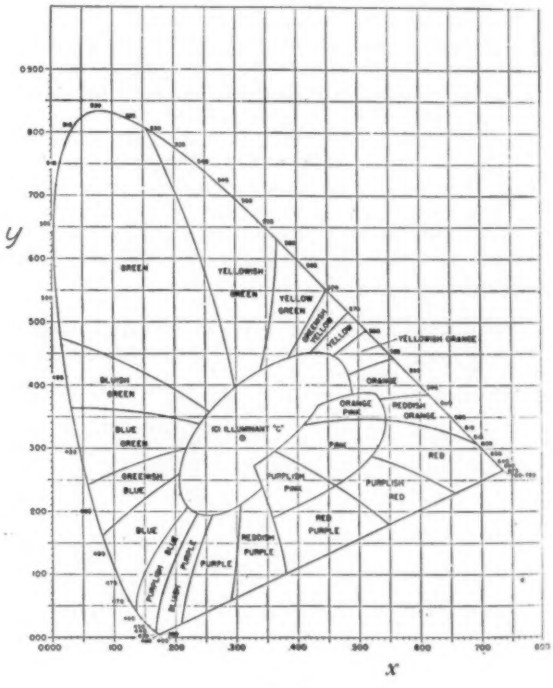


FIG. 18

Suggested Definitions of Color Designations for Self-Luminous Sources. The Chromaticities for Each Designation Are Indicated on the Chromaticity Diagram of the Standard I.C.I. Coordinate System for Colorimetry. Spectrum Chromaticities Are Also Shown, the Wave Lengths Being Indicated in Millimicrons.

Finally, it should again be stated that no tolerance formula can give results better than the measurements on which they are based.

## Literature Cited


1. Adams, E. Q., 1923. A Theory of Color Vision. *Psychol. Rev.* 30, 56-76, illus.
2. Adams, E. Q., 1942. X-Z Planes in the 1931 I.C.I. System of Colorimetry. *Optical Soc. Amer. J.* 32, 168-173, illus.
3. Adams, E. Q., 1946. Developments of the Concept of Chromatic Value (Abstract). *Optical Soc. Amer. J.* 36, 717.
4. American Standards Association, 1942. American War Standard, Specification and Description of Color, Z44-1942 (June 17, 1942).
5. Breckenridge, F. C., and Schaub, W. R., 1939. Rectangular Uniform-Chromaticity-Scale Coordinates. *Optical Soc. Amer. J.* 29, 370-380, illus.
6. Commission Internationale de l'Eclairage, 1931. Proceedings of the Eighth Session. [694] pp., illus., Cambridge, England.
7. Fawcett, G. S., 1944. Sixty Years of Colorimetry. *Phys. Soc. London, Proc.* 56, 8-19.
8. Foss, C. E., Nickerson, D., and Granville, W. C., 1944. Analysis of the Ostwald Color System. *Optical Soc. Amer. J.* 34, 361-381, illus.
9. Gibson, K. S., and Harris, F. K., 1927. The Lovibond Color System. I. A Spectrophotometric Analysis of the Lovibond Glasses. [U. S.] *Natl. Bur. Standards Sci. Paper* 547, 46 pp., illus.
10. Gibson, K. S., and Haupt, G., 1934. Standardization of Lovibond Red Glasses in Combination with Lovibond 35 Yellow. [U. S.] *Natl. Bur. Standards Jour. Res.* (*RP* 718) 13, 433-451, illus.
11. Glenn, J. J., and Killian, J. T., 1940. Trichromatic Analysis of the Munsell *Book of Color*. *Optical Soc. Amer. J.* 30, 609-619.
12. Granville, W. C., and Jacobson, E., 1944. Colorimetric Specification of the *Color Harmony Manual* from Spectrophotometric Measurements. *Optical Soc. Amer. J.* 34, 382-395, illus.
13. Granville, W. C., Nickerson, D., and Foss, C. E., 1943. Trichromatic Specifications for Intermediate and Special Colors of the Munsell System. *Optical Soc. Amer. J.* 33, 376-385, illus.
14. Haupt, G. W., 1937. Statistical Investigation of the Uniformity of Grades of Lovibond Red Glasses (Abstract). *Optical Soc. Amer. J.* 27, 63.
15. Hunter, R. S., 1940. A Multipurpose Photoelectric Reflectometer. [U. S.] *Natl. Bur. Standards Jour. Res.* (*RP* 1345) 25, 581-618; *Optical Soc. Amer. J.* 30, 536-559.
16. Inter-Society Color Council, 1939. A Symposium on Color Tolerance (seven papers by Dimmick, Boring, Newhall, Helson, MacAdam, Judd, and Balinkin). *Amer. Jour. Psychol.* 52, 383-448, illus.
17. Inter-Society Color Council, 1944. Discussion Session on Small Color Differences (several papers and discussion). *Amer. Dyestuffs Reptr.* 33, 11 (May 22, 1944); 12 (June 5, 1944); 13 (June 19, 1944); 14 (July 3, 1944).
18. Jacobson, E., 1942. *The Color Harmony Manual*. 13 v. Chicago, 3, Illinois. (Large chip edition in 1946.)
19. Judd, D. B., 1935. A Maxwell Triangle Yielding Uniform Chromaticity Scales. *Optical Soc. Amer. J.* 25, 24-35, illus.
20. Judd, D. B., and Kelly, K. L., 1939. Method of Designating Colors. [U. S.] *Natl. Bur. Standards Jour. Res.* (*RP* 1239) 23, 355-385, illus.

20a. Kelly, K. L., 1943. Color Designations for Lights. *Optical Soc. Amer. J.* 33, 627-632, illus.

21. Kelly, K. L., Gibson, K. S., and Nickerson, D., 1943. Tristimulus Specification of the Munsell *Book of Color* from Spectrophotometric Measurements. *Optical Soc. Amer. J.* 33, 355-376, illus. [U. S.] *Natl. Bur. Standards Jour. Res.* (*RP* 1549) 31, 55-76, illus.
22. Knudsen, L. F., 1942. A Punched Card Technique to Obtain Coefficients of Orthogonal Polynomials. *Jour. Amer. Stat. Assoc.* 37, 496-506, illus.
23. MacAdam, D. L., 1935. Maximum Visual Efficiency of Colored Materials. *Optical Soc. Amer. J.* 25, 361-367, illus.
24. MacAdam, D. L., 1937. Projective Transformations of I.C.I. Color Specifications. *Optical Soc. Amer. J.* 27, 294-299, illus.
25. MacAdam, D. L., 1945. Colorimetric Specifications of Wratten Light Filters. *Optical Soc. Amer. J.* 35, 670-675, illus.
26. Maerz, A., and Paul, M. R., 1930. A Dictionary of Color. 207 pp., illus. (56 plates). New York.
27. Massachusetts Institute of Technology. [Hardy, A. C.], 1936. Handbook of Colorimetry, 87 pp., illus.
28. Moon, P., and Spencer, D. E., 1943. A Metric Based on the Composite Color Stimulus. *Optical Soc. Amer. J.* 33, 270-277, illus.
29. Munsell, A. H., 1941. A Color Notation. Ed. 9, 74 pp., illus. Baltimore 2, Md.
30. Munsell Color Company, Inc., 1929. Munsell Book of Color. Standard library and pocket-sized editions, illus. Baltimore 2, Md.
31. Newhall, S. M., Nickerson, D., and Judd, D. B., 1943. Final Report of the O.S.A. Subcommittee on the Spacing of the Munsell Colors. *Optical Soc. Amer. J.* 33, 385-418, illus.
32. Nickerson, D., 1938. Use of I.C.I. Tristimulus Values in Disk Colorimetry. U. S. Dept. Agr., 17 pp., illus. [Processed.]
33. Nickerson, D., 1946. Color Measurement and Its Application to the Grading of Agricultural Products. *U. S. Dept. Agr. Misc. Pub.*, No. 580, 62 pp., illus.
34. Nickerson, D., 1946. The Munsell Color System. *Illum. Engin.* 41, 549-560, illus.
35. Nickerson, D., and Newhall, S. M., 1941. Central Notations for ISCC-NBS Color Names. *Optical Soc. Amer. J.* 31, 587-591, illus.
36. Nickerson, D., and Stultz, K. F., 1944. Color Tolerance Specification. *Optical Soc. Amer. J.* 34, 550-570.
37. O.S.A Colorimetry Committee, 1945. Colorimeters and Color Standards. *Optical Soc. Amer. J.* 35, 1-25, illus.
38. Ostwald, W., 1932-1935. The Ostwald Colour Album. (Winsor & Newton, London and New York), 680 color standards.
39. Reimann, G., Judd, D. B., and Keegan, H. J., 1946. Spectrophotometric and Colorimetric Determination of the Colors of the TCCA Standard Color Cards. *Optical Soc. Amer. J.* 36, 128-159, illus., also [U. S.] *Natl. Bur. Standards Jour. Res.* (*RP* 1700) 36, 209-247, illus.
40. Ridgway, R., 1912. Color Standards and Color Nomenclature. [44] pp., illus. Baltimore.
41. Saunderson, J. L., and Milner, B. I., 1944. Further Study of $\omega$ Space. *Optical Soc. Amer. J.* 34, 167-173, illus.
42. Saunderson, J. L., and Milner, B. I., 1946. Modified Chromatic Value Color Space. *Optical Soc. Amer. J.* 36, 36-42, illus.
43. Scofield, F., 1940. A Method of Representing Color. ASTM Bulletin No. 102 (January), p. 11, illus.
44. Scofield, F., 1943. A Method for Determination of Color Differences. National Paint, Varnish & Lacquer Association, Scientific Section Circular 664 (July), 183-189, illus.
45. Scofield, F., Judd, D. B., and Hunter, R. S., 1941. A Proposed Method of Designating Color. *ASTM Bulletin* No. 110 (May), 19-24, illus.
46. Tintometer, Ltd., n.d. Colorimetry. Part I. Lovibond System. Part 2. Lovibond-Schofield System. 24 pp., illus. Salisbury, England.


## Sulphite Mill Modernization Described At TAPPI Hudson Valley Meeting

The Hudson Valley Group of the Technical Association of the Pulp and Paper Industry held its first meeting of the current season on the evening of October 17, 1947 at the Village Inn at South Glens Falls under the chairmanship of Henry W. Fales. The speaker was James E. Foote, vice-chairman of the Empire State TAPPI, who described the modernization effected in the old Algonquin Mill at Ogdensburg by its present operators, the BFD Division of the Diamond Match Co., of Plattsburg.

Mr. Foote said that the plant had been completely remodeled so that at present it is as up to date and efficient a sulphite mill as can be had. The modernization program consisted of complete instrumentation of the acid preparation and sulphite cooking processes. Circulation with direct heating by means of hydroheaters was installed on the four digesters. The water blow was installed and the blowpits remodeled and fitted with agitation. Because of the agitation and the water blow the consistency of the pulp in the blowpits is reduced to about 3% thus allowing pulp to be pumped from the blowpits and permitting the use of a vacuum washer for freeing the stock of the spent cooking liquor.

Mr. Foote described a new set of rifflers which have been installed which serve the purpose of knotters as well as the conventional riffler application. A complete new screen room was also installed embodying the latest thoughts in screen room design. The whole operation is so fitted with recording gages and automatic valves that the operator in each department has before him a continuous picture of how the processes are proceeding.

Preceding Mr. Foote's talk Mr. LeRoy Perry of the New York Power & Light Corp., showed a film "Floating Island" which described the removal of several islands at the Higley Falls, on Raquette River Power House. Mr. Perry gave a running commentary while the film was being shown.

Among those present were: James Foote, Roger Wells, L. N. Poccia, Herbert F. Jacques, S. H. Grimnes, W. F. Curtis, Richard Hinman, F. J. McCourt Wm. J. Mandigo, V. P. Edwardes, Milburn Wells, C. V. Simmons, Edward Hutchins, A. B. Judson, C. T. McGreen, Jr., J. F. Sheehy, Irving P. LaHaise, Peter Bird, Gerald Roider, R. H. Wiles, Russel George, H. L. Field, Thomas Peterson, J. R. Lavigne, R. W. Doe, H. G. Morse, Francis L. Harrington, Stanley Barss, W. M. Leeson, Chas. J. Grant, K. L. Seeber, O. J. Mills, M. P. Bhargava, LeRoy J. Perry, Howard J. Freeman, George T. Clink, Donald W. Wood, G. W. Russell, J. M. Maitland, Smith McLandress, Robert D. Moyniban, Robt. I. Wynne-Roberts, Lawrence T. Ross, J. L. Renehan, Bernard McCabe, Joseph G. Quinn, William Monahan, Samuel Sofia, Henry W. Fales, W. Reed Scull, Chas. Sigvardt and James S. Brown.

# Bleeding Resistance of Asphalted Paper At Elevated Temperature*

**Revision of TAPPI Tentative Standard T 475 m-46**

The test is designed to measure the ability of asphalt-laminated or similarly treated case liners or baling paper to avoid staining the contents of a case or bundle. In this method a piece of the paper to be tested is sandwiched between two pieces of smooth white paper and kept at 150°F. for a definite time under a definite pressure, after which the contiguous white paper is examined for staining by the asphalt.

### Apparatus

1. *Pressure Block.* A block of metal 3 inches square, weighing 4.5 pounds, with a flat and smooth under face. A wooden knob fastened to the top of the block serves as a convenient handle.

2. *Bedplate.* A piece of metal 3 inches square and about ¼ inch thick, having a smooth, flat upper face.

3. *Plate Guide.* This is conveniently made from a 4½-inch square of sheet metal with the corners turned up vertically $1\frac{9}{16}$ inches, to serve as guides for the pressure block.

4. *Metal Separator Sheets,* 3 inches square, made from flat, thin aluminum sheet or heavy foil.

5. *Paper Sheets,* 3 inches square, cut from smooth, white coated or imitation art paper.

6. *Oven* capable of maintaining the specimen assembly at a constant temperature of 150 ± 2°F. (65.5 ± 1°C.).

### Test Specimen

The test specimens shall be 3-inch squares cut in such a way as to be representative of the sample to be tested.

### Procedure

Put the specimens and the dissembled apparatus in the oven at 150°F. for a sufficient time for all to reach oven temperature. Place a specimen between two squares of the white paper, and then place this assembly between two aluminum separator sheets. If desired, up to five of these "sandwiches" may be laid on one another, but separated by single metal sheets, and tested simultaneously. Place the sandwiches on the bedplate in the guide and cover with the pressure block (which exerts a pressure of 0.5 p.s.i.). Accomplish this with as little cooling of the apparatus as possible. Leave the assembly in the oven at 150°F. for 5 hours; then remove, separate the sandwiches, and examine the white paper for staining by asphalt or other exuded material.

Rate the degree of staining as follows, disregarding any staining arising from the edges of the specimens:

| *Rating* | *Staining* |
|---|---|
| No bleeding. | No visible staining. |
| Slight bleeding. | Staining in the form of a few isolated specks only. |
| Moderate bleeding. | Numerous specks, but no blotches or spots over 1/16 inch in diameter. |
| Considerable bleeding. | Numerous specks in the form of spots or blotches over 1/16 inch in diameter. |

* This revised method has been approved as a tentative standard by the Packaging Materials Testing Committee. Criticisms are earnestly requested and should be sent to R. G. Macdonald, Secretary, Technical Association of the Pulp and Paper Industry, 122 E. 42nd St., New York 17, N. Y.

The method has been adopted by the American Society for Testing Materials under designation D 917.

### Report

Report the bleeding as none, slight, moderate or considerable, and describe the nature of any staining.

### Additional Information

The size of the specimen and metal blocks may depart from that specified, provided the pressure amounts to approximately 72 pounds per square foot (0.5 p.s.i.). The pressure, however, does not appear to be very critical, providing it is sufficient for good contact between the white sheets of paper and the test specimens.

Care should be taken that radiant heat does not raise the temperature of the assembly considerably above the indicated temperature of the oven.

## TAPPI Notes

Russell F. Erickson is now assistant resident manager and chief engineer, Rayonier, Inc., Fernandina, Fla.

David B. Kuhe, formerly of the North Carolina Pulp Company, is now mill manager, Cia. Industrias de Atenquique, S. A., Guadalajara, Jalisco, Mexico.

R. S. von Hazmburg, formerly of the Certain-Teed Products Company, is now supervisor of the Asphalt Production Laboratory, U. S. Gypsum Company, Chicago, Ill.

Milton Litvin, formerly of the Heyden Chemical Corporation, is now a graduate student at West Virginia University, Morgantown, W. Va.

Gordon Rowlandson, formerly of the Spruce Falls Power & Paper Company, is now production superintendent, Long Lac Pulp and Paper Company, Terrace Bay, Ont.

## New TAPPI Members

The Executive Committee of the Technical Association of the Pulp and Paper Industry has elected the following to membership:

Charles E. Crawford, Chemist, Bloomer Bros. Co., Newark, N. Y., a 1947 graduate of the New York State College of Forestry.

Ralph B. Murchie, Superintendent, Sulphate Mill (mill under construction), Fraser Companies Ltd., Newcastle, N. B., Canada. Attended Institute of Industrial Arts.

Ronald M. Thomson, Paper Mill Manager, John Collins Ltd., Stoneywood Paper Mill, Denny, Stirlingshire, Scotland. Attended Grosvenor College, Carlisle; and Heriot Watt College, Edinburgh.

Edward F. Thode, Assistant Professor, Department of Chemical Engineering, University of Maine, Orono, Maine, a 1942 graduate of Massachusetts Institute of Technology, with an Sc.D. degree in 1947.

Thomas M. Riddick, Consulting Engineer and Chemist, 369 East 149th St., New York 55, New York, a 1932 graduate of the University of North Carolina with an M.S. degree.